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Deloro Mine Site Cleanup Project

Draft Cleanup Plan
Summary

November 5, 2004

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Ontario Ministry of the Environment

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Preface

This document summarizes the full technical report of the draft cleanup plan for the Deloro Mine Site, created by the Ministry of the Environment's (MOE) engineering consulting firm CH2M HILL Canada Limited (CH2MHILL). This document is intended as a generalized draft for discussion purposes only. The full draft integrated cleanup plan (titled, *Deloro Mine Site Cleanup, Integrated Cleanup Plan – Draft Report*) is available for public review at: www.ene.gov.on.ca, or by contacting Heather Hawthorne, Ministry of the Environment, 133 Dalton Avenue, Kingston, Ontario. Phone: 613-548-6927. The draft integrated cleanup plan will be finalized after public consultation.

Introduction and Background

The Deloro Mine Site Cleanup Project is a multimillion dollar initiative of the Ontario Ministry of the Environment to clean up the abandoned mining, refining, and manufacturing site at Deloro, Ontario. The ministry assumed responsibility for this site in 1979 as remediator of last resort when the site owner failed to comply with ministry orders to stop pollution. The ministry has made significant progress in dealing with the complex and multifaceted environmental issues at the site, and is now consulting on the draft plan to finish the cleanup.

Location

The Deloro Mine Site is in Eastern Ontario about 200 km southwest of Ottawa and 65 km east of Peterborough. The site sits along the banks of the Moira River, beside the eastern boundary of the Village of Deloro (pop. 180).

History

The Deloro mine was the site of nearly 100 years of mining, refining, and manufacturing. It has a rich past and an important place in the history of industry in Canada. Mining at the site began around 1867, and was part of the Madoc Gold Rush, the first discovery of gold in Ontario. Operations at the site evolved over the next century to include not only mining and refining of gold, but also smelting and refining of a number of other elements including arsenic, silver, and cobalt.

The Deloro Mining and Reduction Company was the first in the world to produce cobalt commercially. The company was also a leading producer of stellite, a cobalt-chromium-tungsten alloy. Concentrates from uranium extraction were imported to the site and further processed to extract cobalt and arsenic.

Deloro was a pioneer producer of arsenic-based pesticides, which were produced from the by-products of smelting operations and continued as a main activity at the site until the market collapsed in the late 1950s.

Ownership of the property now known as the Deloro Mine Site was transferred through a succession of entrepreneurs including the Gatling Gold and Silver Mining Company, Canada Consolidated Mining Company, Canadian Goldfields Limited, and the Deloro Mining and

Reduction Company, (which later changed its name to the Deloro Smelting and Refining Company).

In 1961, the Deloro Smelting and Refining Company closed its plant. In 1970, British Oxygen bought Deloro Stellite (a division of the Deloro Smelting and Refining Company). The sale did not include the mine site property, which was transferred to Erickson Construction Company Limited, a subsidiary of M.J. O'Brien. In 1979 Erickson Construction Company Limited abandoned the site. The Ontario Ministry of the Environment assumed responsibility for the environmental cleanup of the site as "remediator of last resort" The property escheated to the provincial Crown in 1987.

Environmental Legacy

At the time the refining and manufacturing operations were shut down in 1961, nearly a century's worth of hazardous by-products and residues (a complex blend of toxic compounds; metals like cobalt, copper, nickel; and low-level radioactive wastes) remained on the property. Arsenic is the main contaminant of concern. Low-level radioactive slag and tailings were produced as a result of the re-refining of by-products from uranium refining. All these materials caused significant environmental impact at the site, including contamination of the site's soil, sediment, surface water and groundwater. In addition to chemical concerns the site was scattered with abandoned mine workings.

Ministry of the Environment Accomplishments

The Ontario Ministry of the Environment (MOE) took control of the site in 1979 when the site owner failed to comply with Environmental Protection Act cleanup orders. Since that time the ministry has spent more than $20.5 million on this project on actions that include:

- Construction of an Arsenic Treatment Plant to treat contaminated groundwater (the plant removes about 99.5 per cent of the arsenic from the contaminated groundwater it treats);
- Establishment of an extensive ground and surface water monitoring network
- Construction of an on-site laboratory to analyze ground and surface water samples
- Locating and sealing abandoned mine shafts
- Demolishing derelict buildings
- Covering eight hectares (ha) of red mud tailings with crushed limestone to eliminate wind and surface water erosion and to address chemistry related issues
- Fencing the entire site to discourage trespassing
- Conducting two off-site assessments: *Deloro Village Environmental Health Risk Study*; and the *Moira River Study* to assess potential off-site impacts to people and the environment.

As a result of ministry actions at the site, the arsenic loading to the river has been reduced by more than 80 percent. For more information on each of these activities, refer to Appendix D, or to the Deloro Web page on the ministry's Web site at www.ene.gov.on.ca.

Finishing the cleanup of the site

Despite significant progress, more work is needed to finish the cleanup and secure the site for the long-term. In April 1997, CH2M HILL Canada Limited (CH2MHILL) was hired by the ministry to develop and implement the plan that would finish the cleanup of the former mining and industrial complex.

Cleanup Objectives, Approach and Criteria

This section reviews the process used in the development of the draft cleanup plan for the Deloro Mine Site and includes information on the objectives for the site cleanup, as well as cleanup approach and criteria.

Deloro Mine Site Cleanup Project -- Overall Objective

The overall objective of the Deloro Mine Site Cleanup Project is to finish the cleanup of this abandoned mining and industrial complex, by isolating and containing wastes, and engineering the site to be safe for people and the environment for hundreds of years.

Additional cleanup objectives

Additional cleanup objectives were developed to ensure the draft cleanup plan:

- Manages wastes over the smallest possible area (reduces the surface area of the wastes)
- Secures the site for the long-term
- Reduces the loading of arsenic and other contaminants to the Moira River
- Complies with appropriate regulations and policy
- Satisfies the general intent of the Mining Act
- Prioritizes implementation of cleanup action according to risk reduction
- Minimizes long-term operation and maintenance of site facilities
- Restores the site to reflect its natural surroundings

These objectives are consistent with cleanup practices elsewhere in the province.

Division of Areas

The overall Deloro Mine Site property, which includes former mine workings, mineral processing facilities and tailings disposal areas, is approximately 202 hectares in area.
To facilitate development of the cleanup plan, the Deloro Mine Site was conceptually divided into four areas based on historical land use and waste disposal practices. These areas are:

- Industrial Area - where smelting and refining of various ores took place
- Mine Area - on both the east and west sides of the Moira River, where mining took place
- Tailings Area - where by-products of the production phase were stored
- Young's Creek Area - which has been impacted from historical releases from the Tailings Area

Quick facts about the Deloro Mine Site

Size: About 202 hectares (ha)

Contaminants of Concern:
- Arsenic, the main contaminant of concern
- Cobalt, copper, nickel
- Low-level radioactive material (represents 2-6 per cent of waste at the site)

Other Materials to be Managed:
- Refining slag
- Mine tailings
- Laboratory wastes
- Demolished materials

Volume of Wastes: About 650,000 cubic metres (m^3)

A cleanup strategy has been developed for each area of the site to deal with each area's unique environmental issues.

Area-specific closure objectives

For each area of the mine site specific closure objectives were developed to help ensure a successful cleanup. Some of these objectives are outlined below.

Area	Closure Objectives
Industrial Area	Reduce low-level radioactivity to background levels
	Remove wastes from the 100-year floodplain
	Consolidate and isolate wastes from the environment
	Ensure engineered facilities are designed to be safe for hundreds of years
Mine Area	Consolidate highly contaminated materials
	Restore area to blend in with natural surroundings
Tailings Area	Contain tailings for the long-term
	Manage contaminated seepage
	Revegetate the area to match natural surroundings
Young's Creek Area	Prevent increased contaminant loading to the Moira River
	Ensure engineered facilities are designed to be safe for hundreds of years
	Restore area to blend in with natural surroundings

Cleanup Approach

Strategic direction: onsite management of wastes through isolation and containment.

The Ministry of the Environment decided in the early 1990s, that the most viable solution for the management of contamination at the Deloro Mine Site is onsite management through isolation and containment techniques.

Wastes will be isolated and contained onsite following the Site Specific Risk Assessment (SSRA) approach, under MOE's *Guideline for Use at Contaminated Sites in Ontario* (1997). Risk assessment is a scientific technique which estimates the risk posed to people, plants, wildlife and the natural environment from exposure to a contaminant. Results of the SSRA are used to determine how much cleanup needs to happen before the site is considered safe for people and the environment.

For more detailed information on the Site Specific Risk Assessment approach, and the ministry's guidance documents, please refer to the ministry's Web site: www.ene.gov.on.ca. The SSRA for the Deloro Mine Site is currently in development. The results will be used to establish the extent of the cleanup.

Cleanup Criteria

In order to meet the objectives of site cleanup, several specific, measurable criteria, or targets for cleanup were developed under three main categories: physical, chemical and radiological. The cleanup criteria were based on a detailed review of the applicable federal and provincial legislation, guidelines and policies and the application of engineering principles. Each of these criteria had to be met in the development of the cleanup plan.

Physical Cleanup Criteria

Design Service Lives – The cleanup plan had to ensure that engineered facilities used to isolate and contain wastes are designed to be safe for hundreds of years. The chart below outlines the design life of key engineered components proposed for the Deloro Mine Site:

Engineering Feature	Design life
Primary leachate collection system	greater than 100 years
Compacted clay liners	thousands of years
Manufactured (geomembrane) liners in contact with raw leachate	150 years
Manufactured (geomembrane) liners in secondary system	greater than 200 years
Secondary leachate treatment system	1,000 years
Tertiary leachate collection system	greater than 1,000 years

Design Floods – The cleanup plan had to ensure all contaminated materials within the 100-year floodplain along the Moira River are removed. This is the area that would likely be affected in

the event of a storm resulting in major flooding. Those contaminated materials outside the floodplain must be isolated from the environment.

Seismic Considerations – The cleanup plan had to ensure engineered facilities were strong enough to endure the maximum earthquake activity possible for the area.

Perpetual Disruptive Forces - The cleanup plan had to be designed to minimize, or eliminate the effects of perpetually disruptive forces, including: wind erosion, water erosion due to flooding, ice accumulation, frost penetration, and weathering. The plan also had to be designed to minimize the possibility of root penetration, burrowing animals and people.

Chemical Cleanup Criteria

Human Health - The cleanup must ensure protection of human health from cancer-causing and non-cancer causing materials.

Aquatic - The cleanup must ensure protection of aquatic species. To that end, the cleanup must be designed to ensure the current/interim Provincial Water Quality Objectives (PWQO) are met, on average, at all locations in the Moira River and Young's Creek at Highway # 7. To ensure this, the cleanup plan must be designed to achieve a further 90 percent reduction in arsenic discharge to the Moira River.

The PWQO will ideally be met at all locations in the Moira River and Young's Creek within the site boundaries to the extent possible. The Moira River and Young's Creek will be considered a mixing zone north of Highway # 7. Conditions in the mixing zone may exceed the PWQO but must not be acutely toxic to aquatic life or cause irreversible ecological damage. The Moira River and Yong's Creek intersection points with Highway # 7 are the key reference points for meeting the current/interim PWQOs.

Terrestrial - The cleanup must result in the long-term protection of terrestrial habitat.

Radiological Cleanup Criteria

The cleanup plan must reduce low-level radiation to background levels at ground surface.

For more information on closure criteria, please see: *Deloro Mine Rehabilitation Project - Development of Closure Criteria, October 1998.*

Developing the draft cleanup plan

This section outlines the process followed in the development of the draft cleanup plan for the Deloro Mine Site, including an explanation of the various scientific and engineering reports created in the process.

The development of a cleanup plan is a complex process requiring the specialized and combined expertise of engineers, hydrogeologists, scientists, biologists, risk assessors, and toxicologists.

An extensive team of technicians, scientists and engineers from CH2MHILL developed the draft cleanup plan. The plan was also reviewed by scientific and engineering experts in the Ministry of the Environment, and by the ministry's three project liaison committees (the Public Liaison Committee, the Technical Liaison Committee, and the MOE Technical Committee).

Development of a comprehensive cleanup plan for a site as large and complex as the Deloro Mine Site required a very detailed understanding of the site itself, including the exact nature, extent, and location of contamination, as well as a detailed understanding of ground and surface water flow, 100-year floodplain mapping, site geology, and ecology. Outlined below is a condensed summary of steps followed in the development of the plan.

Technical investigations – involves scientific analysis necessary to define the extent and nature of contamination; to determine current environmental conditions (i.e. soil, surface water, groundwater, air, human health risk, and ecologic conditions). Technical investigations also determine the feasibility of various cleanup options. CH2MHILL conducted a number of technical investigations to address outstanding site-wide and area-specific questions. For a partial list of those investigations see Appendix E.

Alternatives reports -- As part of the development of the cleanup plan, CH2MHILL evaluated a broad range of conceptual cleanup methods (rehabilitation alternatives) and identified a recommended alternative for each of the four areas of the mine site. For a detailed review of the alternatives considered for each area of the site, please refer to the rehabilitation alternatives reports on the ministry's Web site, www.ene.gov.on.ca :

- *Deloro Mine Site Cleanup - Industrial Area Rehabilitation Alternatives, December 2003*
- *Deloro Mine Site Cleanup - Mine Area Rehabilitation Alternatives, October 2003*
- *Deloro Mine Site Cleanup - Tailings Area Rehabilitation Alternatives, October 2003*
- *Deloro Mine Site Cleanup - Young's Creek Area Rehabilitation Alternatives, May 2003*

Closure plans – Closure plans take the recommended cleanup alternative to the next level of development, and include a preliminary engineering design for each area. The closure plans listed below are found on the ministry's Web site, www.ene.gov.on.ca :

- *Deloro Mine Site Cleanup – Industrial Area Closure Plan, August 2004*
- *Deloro Mine Site Cleanup – Mine Area Closure Plan, August 2004*
- *Deloro Mine Site Cleanup – Tailings Area Closure Plan, August 2004*
- *Deloro Mine Site Cleanup – Young's Creek Area Closure Plan, August 2004*

The Draft Cleanup Plan – The draft Cleanup Plan integrates the four area-based Closure Plans to provide a comprehensive summary of the cleanup efforts proposed for the entire Deloro Mine Site.

Environmental Legacy – In detail

Waste Volume Inventory

Technical investigations allowed the consultant to more accurately determine the nature and extent of contamination. The chart below summarizes the volume of waste material at the Deloro Mine Site. The main contaminants of concern at the site are arsenic, cobalt, copper, and nickel. Low-level radioactive waste is also a contaminant of concern.

Area	Approx. size of area – hectares (ha)	Waste Type	Approx. Volume cubic metres (m^3)
Industrial Area	25	Highly contaminated waste (arsenic, including calcium arsenate/arsenite stockpile and gold mine tailings) and mixed radioactive slag and radioactive tailings	262,000
		Radioactive and non-radioactive slag	39,500
		Demolition ruins	4,000
Main Mine Area and Remote Mine Area	117	Highly contaminated waste and low-level radioactive slag	32,500
Tailings Area	13	Red mud tailings	45,000
Young's Creek Area (onsite)	47	Contaminated sediments (some radioactive) and contaminated deeper soils	199,000
Young's Creek Area (offsite)	19	Contaminated shallow sediments	68,000
		Total	**Approx. 650,000**

Low-Level Radioactive Material

About two to six per cent of the total waste at the Deloro Mine Site is contaminated with low-level radioactivity. Operations at the Deloro Mine Site in the 1930s to 1950s involved the reprocessing of uranium and radium (Ra-226) residues from the Eldorado refinery in Port Hope for the recovery of cobalt, other metals, and arsenic. The nature and extent of low-level

radioactive materials at the site was summarized in a report titled *Deloro Mine Site Cleanup Project - Extent and Character of Radioactive Materials, June 1999.*

> **Radioactivity 101** – There are three types of radiation emitted from the naturally occurring radioactivity present in all rocks and soils: alpha, beta and gamma radiation. Alpha radiation is a particle that is readily stopped in air or by a sheet of paper. Beta radiation is a smaller particle that travels further in air but is also readily stopped by 1-2 cm of water or by the near-surface of the body. Gamma radiation is a form of electromagnetic radiation, similar to light or radiowaves, but of greater energy and is more penetrating than either alpha or beta radiation.
>
> Uranium is a naturally occurring radioactive element that is widely distributed on earth.
>
> Radon is a gas that is the naturally occurring by-product of uranium and radium. Since all soils contain some uranium and radium, our atmosphere and our homes all contain radon.
>
> Units of measurement - The S.I. (Système International de Unités) unit of dose is the sievert (Sv) or millisievert (mSv), 1 mSv = 1,000 μSv. The S.I. unit of radioactivity is the Becquerel (Bq) and equals 1 nuclear disintegration per second.

Types of Radioactivity at the Deloro Mine Site – There are two main types of low-level radioactive wastes at the Deloro site – tailings and slag. Radioactive tailings are found in the Industrial, Tailings, and Young's Creek (onsite) Areas. Radioactive slag is found in the Industrial and Main Mine Areas. A quantity of soil contaminated with low-level radioactive slag is also present at the site. This material was removed from the Village of Deloro as part of the Deloro Village Environmental Health Risk Study and will be included in the site cleanup.

Background Radioactivity Levels -- Typical background radiation fields in Ontario are between 0.03 microsieverts per hour (μSv/h) and 0.06 μSv/h.

Gamma radiation fields at the Deloro Mine Site vary from background levels to as high as 15 μSv/h measured at one metre above ground surface.

Measurements of exterior radon gas at the Deloro Mine Site show concentrations are within the range of natural background levels in the Great Lakes region of Ontario.

The average background concentrations of uranium in surface water and groundwater are 0.1 μg/L and 13.5 μg/L, respectively. The concentrations detected onsite were within the range of these natural background levels in Ontario. The concentrations detected were also less than the Health Canada Guidelines for Canadian Drinking Water Quality and the Ontario Drinking Water Standards (ODWS) Maximum Acceptable Concentration (MAC) of 0.6 Becquerels per litre (Bq/L) for Ra-226 and 0.1 mg/L for uranium.

For more information on radioactivity issues see *Deloro Mine Site Cleanup – Project Description, November 2002.*

Management of Low-Level Radioactive Materials

All low-level radioactive materials at the site will be excavated and/or covered in the Industrial Area and other areas of the site to reduce the radiation fields to background levels of 0.03 to 0.06 μSv/h

Evaluation of Alternatives

This section continues the review in the development of the draft cleanup plan, and includes a description of the rigorous process used to develop and screen cleanup alternatives for each area of the mine site.

As discussed above, the Deloro Mine Site Cleanup Project is being conducted according to the *Guidelines for Use at Contaminated Sites (MOE, 1997)* following the Site Specific Risk Assessment (SSRA) option. The approach has been adapted or enhanced to meet other regulatory or best management practices including the *Canadian Environmental Assessment Act* (CEAA).

Alternatives Selection

Cleanup strategies for the Deloro Mine Site Cleanup Project were selected using a very detailed and rigorous review process. A thorough review of scientific literature was used to develop a long list of possible conceptual cleanup methods for each area of the site. A four step process was used to develop and review cleanup alternatives. To be considered further each potential method had to meet all project cleanup objectives. Experimental methods were not considered.

Cleanup methods were evaluated using 16 different measures of effectiveness that considered technical, social, environmental, and cost considerations. All evaluation criteria carried equal weight in the process.

For each area of the site, each comprehensive cleanup alternative was compared to others. For the Industrial Area, 16 cleanup alternatives were considered, for the Mine Area three, for the Tailings Area six, and for the Young's Creek Area four.

<u>The Four Step Evaluation</u>

Step 1 - Meeting cleanup objectives

To be considered, each potential method had to meet the overall, site-specific and area-specific cleanup objectives for the Deloro Mine Site Cleanup Project. Experimental methods were not considered.

Step 2 – First screening evaluation

Conceptual cleanup methods were evaluated in a screening process to determine:

- **Effectiveness** -- Can the cleanup method reduce unacceptable impacts to people and the environment?

- **Satisfaction of government regulations and guidelines** -- Can the cleanup method meet relevant government legislation and guidelines?
- **Pre-established design closure criteria** – Is the cleanup method likely to satisfy the design criteria specific to each area of the site?

Cleanup methods that could meet all three criteria were then advanced to be considered as part of a **comprehensive cleanup alternative,** one that combined primary cleanup methods (those that would best address contamination issues) with enhancing features (those that would supplement cleanup methods and provide additional layers of safety).

Step 3 – Second screening evaluation

Evaluation of Comprehensive Cleanup Alternatives

Comprehensive cleanup alternatives were evaluated in a screening process similar to Step 2.

Step 4 – Detailed Evaluation Criteria

Comprehensive cleanup alternatives that could meet all three criteria were then advanced to another screening process using a number of detailed evaluation criteria.

For each area of the site, each comprehensive cleanup alternative was compared to others using the detailed evaluation criteria listed below. **All criteria carried equal weight in the evaluation process.**

Technical Considerations
- Reliability
- Compatibility with existing system
- Ease of implementation

Costs
- Operation and maintenance costs
- Capital costs

Social Considerations
- Public acceptance
- Risk to public
- Constraint for recreational use
- Negative impact to private properties
- Visual character of the area
- Risk to workers

Natural Environment
- Geochemistry
- Terrestrial habitats
- Floodplain
- Fish habitats

A cleanup strategy for each area of the site was recommended at the end of the evaluation process. That recommendation was further developed in a Closure Plan for each area of the mine site. Each recommended alternative satisfied the greatest number of criteria.

The Draft Proposed Cleanup Plan – Overview by Area

The following section outlines in general terms, the draft cleanup strategy for each area of the mine site. For more detailed information, please refer to the *Deloro Mine Site Cleanup-Integrated Cleanup Plan, Draft Report on the ministry's Web site, www.ene.gov.on.ca.*

Deloro Mine Site Draft Cleanup Plan -- Industrial Area

Concentrated industrial activity took place in this area from about 1867 to 1961. Activities included smelting, refining, and manufacturing of materials including arsenical-based pesticides, refined gold, refined silver, cobalt metal, stellite, and machine parts. This is the most heavily contaminated part of the site. Most of the ongoing arsenic loading to the Moira River comes from this area, and the Mine Area.

Area: 25 ha

Contaminants of Concern: Calcium arsenate/ arsenite and, slag and gold mine tailings contaminated with arsenic, cobalt, copper, lead, mercury, nickel, ferric arsenate (sludge from the Arsenic Treatment Plant), and low-level radioactive materials.

Volume of Wastes: Approximately 305,000 m^3

CLEANUP STRATEGY FOR THE INDUSTRIAL AREA

Consolidate and cover wastes with an engineered cover combined with groundwater and surface water flow diversion to enhance the existing collection/treatment system.

Overview

Consolidation of waste and capping

The most highly contaminated wastes will be placed in a waste consolidation area and capped with an engineered cover that is 1.5 metres thick. This will reduce the footprint (the total area) of the wastes, and will isolate them from the environment.

The soil along the western bank of the Moira River, once the site of the arsenic baghouse, will be removed and placed under the engineered cap. The riverbank will be reconstructed with "clean" fill.

Less contaminated materials will be covered with an engineered clay cap 1.5 metres thick to isolate them from people and the environment.

Ground and surface water diversion

Groundwater and surface water flow will be diverted away from contaminated materials. Clean groundwater will be diverted away from the wastes and under the engineered cover by a passive groundwater interceptor well network to be located near the western boundary of the Industrial Area. Extensive grading and interceptor ditches will be built to drain or divert surface water from the engineered cover.

The existing groundwater collection/treatment system (the Arsenic Treatment Plant) will continue to operate.

Demolition of unsafe structures

Unsafe structures and tanks will be demolished and consolidated with existing ruins.

Design Description

Site Preparation

To prepare the Industrial Area for construction, a number of actions will take place including:

- Establishing controls such as security fencing, signage, and air monitoring equipment, to protect the environment and human health,
- Mobilizing equipment (excavators, trucks, site trailers, and other equipment),
- Building access roads,
- Clearing land (trees may be mulched and reused on the site as cover)
- Establishing temporary services such as site trailers, utilities, and a decontamination pad.

Consolidation of Selected Wastes

The objective of waste consolidation is to reduce the footprint of the most highly contaminated wastes and to eliminate contact with ground and surface water.

The Industrial Area contains about 460,000 cubic metres (m^3) of uncontaminated and contaminated soil. The most highly contaminated material (highly leachable waste), has been defined, by the ministry's consultant, as waste with arsenic concentrations exceeding 4,000 parts per million (ppm).

Less contaminated material (marginally leachable waste) has been defined as waste with arsenic concentrations less than 4,000 ppm. Highly contaminated material in the Industrial Area will be consolidated under an engineered cover.

Less contaminated material will be covered with an engineered clay (simple earth) cap, along with low-level radioactive slag.

The Industrial Area contains approximately 262,000 m^3 of highly contaminated waste, approximately 4,000 m^3 of demolition/ruin rubble, approximately 39,500 m^3 of slag, and 900 m^3 of slag and soil removed from the Village of Deloro with slightly elevated levels of low-level radioactivity.[1] In addition, approximately 32,500 m^3 of highly contaminated waste and low-level radioactive slag will be transported from the Mine Area for consolidation under the engineered cover in the Industrial Area.

If demolition/ruin rubble is not contaminated, it may be used as cover material along the riverbank. The radioactive and non-radioactive slag will be used as backfill in the deeper excavated areas to the north and south of the proposed waste consolidation area.

The reuse of slag as backfill reduces the cost of importing "clean" fill to the site for excavated areas and the cost of placing an engineered clay cap over the slag to prevent exposure to low-level radiation or dust. The radioactive and non-radioactive slag occupies an area of approximately 17,000 m^2 and ranges from 1.0 to 3.1 m in average thickness.

All low-level radioactive materials will be excavated and/or covered in the Industrial Area and other areas of the site so that radiation fields will be reduced to background levels of 0.03 to 0.06 μSv/h.

Through the excavation and consolidation of about 131,000 m^3 of highly contaminated waste from the riverbank and north and south sections of the Industrial Area, the footprint of highly contaminated waste will be reduced from about 236,700 m^2 to about 60,000 m^2.

Riverbank Excavation and Reconstruction

About 620 m of contaminated materials along the west bank of the Moira River, adjacent the Industrial Area, will be excavated and the river bank will be reconstructed. This section of the west bank includes the area where the arsenic baghouse operated.

About 10,800 m^3 of waste soil will be excavated from this area. Contaminated material will be removed using techniques to prevent sediment from suspending in the water and being carried downstream. Contaminated material from the riverbank will be consolidated with other material under the engineered cap.

During reconstruction of the riverbank, the configuration of the river will be maintained as closely as possible to existing conditions of bank height, slope, and floodplain.

A more detailed description of this component is found in the report, *Deloro Mine Rehabilitation Project - Riverbank Reconstruction Alternatives for the Industrial Area, March 2002.*

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[1] The low-level radioactive slag transferred from the Village of Deloro is mixed in a matrix of soil contaminated with arsenic and will be placed under the engineered cover, unless the soil is found not to be highly contaminated.

River Diversion -- During the construction period, the Deloro dam or other flow diversion measures will be used to reduce flow in the river to a level that will expose all materials to be removed from the riverbank.

Streambed Protection, Erosion, and Sediment Controls – Every effort will be made to minimize the impact of construction on the existing streambed. No heavy equipment will work in or use the streambed for access during construction. Sediment and erosion protection procedures will be put in place during all phases of cleanup construction to ensure adequate protection of the stream habitat.

Measures will be implemented to prevent sediment from entering the stream or being deposited in the streambed during the removal of materials. Erosion protection will be used at the construction site to prevent runoff of sediment during the construction activities. Erosion protection will consist of silt curtains and straw bale dams. Details of the onsite erosion protection plan will be documented in the contract specifications prior to construction.

Engineered Cover

An engineered cover will be placed over the highly contaminated wastes to:

- Prevent precipitation from filtering through and coming in contact with highly contaminated waste and the underlying groundwater
- Prevent exposure of highly contaminated waste to people and the environment
- Eliminate contact with surface water

Construction of Engineered Cover -- The engineered cover will be placed over an area of approximately 60,000 m^2. Details of the construction of the engineered cover are provided below.

Hybrid Poplar Tree Cover

A hybrid poplar tree cover will be one component of the engineered cover, and is one of the technologies the ministry will use to prevent precipitation from filtering through contaminated wastes. A hybrid poplar tree cover will be placed on top of the engineered cover to manage water and reduce and/or stop precipitation. The cover design will include moisture retention layers to hold excess moisture until it can be taken up by the tree roots in the summer growing season.

The treed cover concept takes advantage of the tremendous potential water uptake capability of tree species such as the locally common poplar and red maple. When planted at an average density of one tree per 3 m^2, poplars at the Deloro Mine Site have the potential to draw up to 633.8 mm of water in a growing season from April to November. Average annual precipitation in the Deloro area is approximately 900 millimeters (mm); so theoretically, a treed cover has the potential to draw up most of the moisture.

For more detailed information on the hybrid tree cover, please refer to *Deloro Mine Site Rehabilitation Project – Feasibility Study for a Combined Soil Cover and Poplar Tree Cap in the Tailings Area, May 2002.*

Engineered Cover Design

Soil Layer	Depth Centimeters (cm)	Rationale
Upper Soil Profile	*Primarily intended to support the poplar trees and provide water storage capacity*	
Silty Loam Topsoil	15	Provides the initial rooting medium and the nutrients, organic material, and trace metals necessary for initial plant growth
Silty Clay Loam	35	Provides soil moisture storage capacity during the non-growing season and facilitates deeper rooting
Lower Soil Profile	*Further minimize percolation, permit drainage and provide additional storage capacity to increase the effectiveness of the cover during non-growing season*	
Compacted Clay	30	Acts as a restrictive barrier to minimize percolation of water into the underlying drainage layer
Sand	25	Acts as a water collection, storage, and transport system for water that penetrates the upper layers especially during the non-growing season. Collected water is diverted away from the Industrial Area
Manufactured (geosynthetic) Clay Liner	NA	Forms a secondary infiltration barrier of the engineered cover
Compacted Clay	50	Acts as a secondary restrictive barrier layer to minimize percolation of water into the underlying waste

Site Revegetation

Once completed, the engineered cover will be vegetated with grass. The grass cover is intended for short-term erosion control until the poplar tree cover is well established. Grass will eventually be shaded out as the canopy of the trees develops. With maturity, the thick root system of the trees will hold the soil together and the canopy of leaves will shield the ground from rain and erosion. When the leaves fall in the autumn, they will contribute to the mulch at the site and the overall capacity of the system to hold water. With time, the cover will become a mature forest with little wind or water erosion.

Engineered Clay Cap

An engineered clay cap (known as a simple earth cap) will be placed over the less contaminated (marginally leachable) soil that will remain following the excavation and consolidation of the highly contaminated material. The design objectives for the engineered clay cap are to:

- Prevent precipitation from filtering through and coming in contact with highly contaminated waste and the underlying groundwater
- Prevent exposure to people and the environment
- Eliminate contact with surface water

Engineered Clay Cap Design

The basic design of the 150 cm engineered clay (simple earth) cap is:

- 15 cm of topsoil
- 50 cm of compacted clay or other low permeability material
- 85 cm of "clean" or non-leachable, non-bioavailable (e.g. slag) backfill

With a thickness of 1.5 m, this design will minimize the risk of mammals burrowing into the underlying contaminated soils. This is a requirement of the Screening Level Ecological Risk Assessment, completed for the site.

For more details on the proposed design of the engineered clay cap, please refer to the draft Integrated Cleanup Plan section 2.1.

Ground and surface water diversion

Installation of Groundwater Interceptor Well Network

Groundwater in the area of the Deloro Mine Site flows naturally from west to east, from the direction of the Village of Deloro through the mine site, and discharges to the Moira River. Currently, as groundwater flows through the site it picks up the contamination deep in the soil, and carries it to the river. The groundwater collection system already in place, intercepts much of this contaminated groundwater and pumps it to the Arsenic Treatment Plant for removal of arsenic and other metals.

The proposed cleanup strategy for the Industrial Area involves diverting groundwater before it gets to the mine site. In order to achieve that, a passive groundwater interceptor well network (GIWN) will be constructed.

The GIWN will include a 900 metre (m) horizontal well placed several metres into the bedrock on the west side of the Industrial Area. Eight vertical pressure relief wells will extend 30 m into the deeper bedrock. The vertical pressure relief wells will flow by artesian pressure and will connect to, or be in close proximity of, the horizontal well.

The GIWN will lower the water table under the wastes to below the bedrock surface and divert clean groundwater from the wastes. The clean groundwater will be discharged to the Moira River.

Since it will take some time for the GIWN to lower the groundwater from beneath the waste area, the existing groundwater pumping stations will continue to operate until groundwater pumping and treatment are no longer required.

For more information on the GIWN see the *Industrial Area Closure Plan.*

Demolition of Buildings/Tanks and Resizing/Consolidation of Ruins

Most buildings at the site have already been demolished to some extent or are in various states of ruin. The remaining buildings are currently unused and pose potential safety hazards.

The ministry is considering preserving a few remaining structures as part of a heritage plan for the site. Those buildings include the powerhouse building, concrete trestle piers of the former primary treatment building, portions of the castings building walls, and the former powder house/magazine. The Arsenic Treatment Plant and the parking garage will be retained. With the exception of those structures the ministry is able to keep, all aboveground structures at the Deloro Mine Site will be demolished to ground level as part of the cleanup.

Uncontaminated demolition materials may be used for erosion protection as part of the reconstruction of the riverbank. Contaminated demolition materials will be consolidated and managed onsite.

Building materials, buildings in which low-level radioactive materials were handled will be tested for radioactivity before they are demolished. Those buildings or portions of buildings, found to contain low-level radioactive contamination will be moved into the waste consolidation area and capped with the engineered cover.

In addition to the buildings and infrastructure ruins, there is a large amount of rubble and waste spread in small piles around the Industrial Area. This material will be collected to improve the appearance of the site. All demolition materials will be reduced in size, where possible.

Uncontaminated wood waste will be reduced using a chipper, and used as a conditioner in the topsoil and engineered clay (simple earth) cap, or composted onsite. For more information on the demolition work required, including the locations of the buildings, tanks, and building ruins, see the *Industrial Area Closure Plan*.

Leachate Treatment

The ministry has implemented various strategies to reduce the arsenic loading to the Moira River since assuming control of the site in 1979. The Ontario Clean Water Agency (OCWA) operates the Arsenic Treatment Plant (ATP) and groundwater collection system on behalf of the ministry. Annual average withdrawal rates of approximately 100,000 m^3/year have had a significant positive impact on Moira River water quality. The arsenic loading to the Moira River has been reduced by more than 80 percent to an annual average of less than 10 kg/day, since the ATP was placed into operation in 1983.

The average annual arsenic concentrations in the Moira River decreased from 0.33 milligrams per litre (mg/L) in 1979 to an annual average of less than 0.08 mg/L since 1991 as measured at the Highway # 7/Moira River monitoring station.

The ATP will receive increased flows from collection and pumping of groundwater from the Mine Area (Tuttle Shaft), and leachate from the Tailings Area and the Young's Creek Area. However, groundwater diversion in the Industrial Area will gradually result in reduced flow rates from existing pumping stations and will ultimately result in a decrease in overall flow to the

ATP. Contaminant concentrations are expected to decrease with time as contaminated groundwater is removed from beneath the waste.

Key performance indicators for the Industrial Area

The draft cleanup strategy for the Industrial Area is expected to achieve the following:

- Capping of the entire Industrial Area will eliminate contact of surface water runoff with contaminated wastes/soils
- The engineered cover/hybrid poplar trees (over consolidated highly contaminated wastes) will allow only about four percent infiltration of annual precipitation
- The passive GIWN will:
  - Intercept approximately 960 m^3/day of clean groundwater before it passes through the site
  - Completely dewater wastes; this is necessary since current groundwater flow through the highly contaminated wastes in the Industrial Area is responsible for the majority of arsenic loading (approximately 80 percent) to the Moira River
  - Result in relatively low interference with the Deloro Village potable well (less than 2 m)

- Estimated reduction in arsenic loading to the Moira River, as a result of the waste consolidation, capping, and groundwater interception measures:

Arsenic loading to the Moira River	**Percentage reduction**
52.1 kg/day (1979)	
<10 kg/day (current -since 1983)	80 per cent reduction from 1979
Approximately less than 1 kg/day to achieve current/interim PWQO in the Moira River downstream of the site (once cleanup is complete).	98 per cent reduction from 1979 levels

Implementation of the cleanup strategy for the Industrial Area will provide safe, long-term containment of all Industrial Area wastes, including low-level radioactive materials.

Deloro Mine Site Draft Cleanup Plan -- Mine Area

Gold mining at the site took place over a period of about 35 years from about 1867 to 1902. Mine shafts were scattered throughout the site. The deepest mine shaft was the Gatling Shaft at a depth of approximately152 metres. The ministry located and sealed all major mine shafts, and remediated all other mine features from 1993-1995. The draft proposed cleanup strategy for the Mine Area deals with remaining waste rock and contaminated soils.

Area: Main Mine Area - 3 ha
Remote Mine Area - 114 ha

Contaminants of Concern: Arsenic, low-level radioactive slag

Volume of Wastes: Approximately 32,500 m^3

Cleanup Strategy for the Mine Area

Relocation/consolidation of highly contaminated wastes to the Industrial Area, placement of a soil cover in the remaining areas and treatment of groundwater from the Tuttle Shaft.

Overview

Consolidation of wastes

Highly contaminated materials (including radioactive slag) will be excavated and relocated to the Industrial Area, where they will be consolidated under the engineered cover, 1.5 metres thick. "Clean" fill will replace the waste materials and the area will be vegetated.

Capping

Less contaminated areas will be covered with an engineered clay cap 1.5 metres thick.

Waste rock will be covered with a geofabric filter, clay, topsoil, (minimum total thickness 0.65 metres thick) and then vegetated.

Groundwater treatment

Groundwater will continue to be pumped from the Main Mine Area, and treated at the Arsenic Treatment Plant.

Design Description – Proposed Mine Area Cleanup

Site Preparation

Site preparation work will include:

- Mobilizing equipment (excavators, trucks, site trailers, and other equipment),
- Construction of temporary access roads, and establishing temporary services,
- Clearing vegetation and trees (to be kept to a minimum to preserve the natural condition of the site).

Excavate Highly Contaminated Waste and Impacted Soils

About 21,600 m^3 of highly contaminated waste/soil in the Main Mine Area will be excavated, consolidated with other highly contaminated wastes and placed under the engineered cover in the Industrial Area.

Excavated areas will be backfilled with "clean" fill material and compacted. The fill will be covered with a 0.15 m topsoil layer and vegetated. If the remaining soils are found to be contaminated to a lesser extent, or elevated risks to people and the environment are still present, an engineered clay cap (a simple earth cap) will be used to cover the excavated areas.

Selected soils in the Remote Mine Area will also be excavated and consolidated in the Industrial Area (approximately 7,800 m^3). Excavated areas will be backfilled with "clean" fill material.

In the alternatives report for the Mine Area, a cover thickness of 650 mm was selected to provide an infiltration barrier plus a suitable growing medium for plants. However, as a result of the draft Site Specific Risk Assessment, the capping thickness was increased to 1,350 mm for clay/fill materials and 150 mm for topsoil, totaling 1,500 mm. This will reduce the potential for exposure to contaminants by burrowing animals and root penetration.

The waste rock areas will be covered with a manufactured filter (geofabric), 500 mm of clay, and 150 mm of topsoil since the contaminants in these areas are not considered bio-available, and burrowing animals and tree roots are not expected to reach the underlying impacted materials.

About 5 m^3 or less of low-level radioactive slag (1 – 2 microsieverts per hour (µSv/h)) is in an area adjacent to the Tuttle Shaft. This material will be removed and consolidated with similar materials in the Industrial Area. The excavation will be filled in with "clean" fill material and then capped with an engineered clay cap.

Following completion of site cleanup (i.e. surface water control features, waste excavation and consolidation, cover/cap placement, site grading), the Main Mine Area and selected Remote Mine Areas will be landscaped and seeded with a mixture of grasses in order to stabilize the surface and limit erosion. The cover/cap will also be vegetated with trees and shrubs to increase the water uptake by plants.

Cover Waste Rock and Marginally Leachable Soil and Vegetate

Less contaminated soils in the Main Mine Area will be covered with layers of topsoil, fill, and compacted clay materials. The topsoil provides the initial rooting medium for the cover vegetation.

The fill material will be deep enough to prevent roots and burrowing animals from being exposed to the contaminated soils below. The compacted clay layer will minimize percolation of water into the materials below.

Accumulations of waste rock from historical mine activities have been identified in both the Main and Remote Mine Areas. Waste rock will be isolated from the surrounding environment.

The first step will be to regrade the waste rock with heavy machinery so that stormwater runoff is directed away from the covered waste rock. The regraded piles will be covered with a manufactured filter (geofabric) to simplify the installation of cover materials. Clay will then be used to cover the geofabric filter to a depth of 0.5 m to help prevent water from seeping through. Vegetation and trees will be planted in a 0.15 m topsoil layer, placed above the clay layer to blend with existing conditions adjacent to the affected area and graded to promote stormwater runoff. The total depth of the cover material will be a minimum of 0.65 m.

Upgrade Tuttle Shaft Pumping System

The Tuttle Shaft is a former mine shaft in the Main Mine Area. Groundwater collects in the shaft naturally, and eventually flows to the Moira River. The ministry capped the shaft in 1994. A pump system is used to direct contaminated groundwater to the equalization pond and Arsenic Treatment Plant.

The Tuttle Shaft currently flows by gravity under artesian conditions to the Moira River, for nine months of the year. At this time, the Tuttle Shaft pump is only operated during low-flow conditions in the Moira River, a period of two to five months during the summer and fall. As part of the cleanup proposed for the Mine Area, groundwater collected in the Tuttle Shaft will be pumped on a year-round basis and treated at the Arsenic Treatment Plant. This will eliminate the artesian discharge of arsenic-contaminated groundwater to the Moira River.

Key performance indicators for the Mine Area

The draft cleanup strategy for the Mine Area is expected to achieve the following:

- The highly contaminated wastes will be excavated and consolidated under the engineered cover, eliminating these sources in the Main Mine Area and the Remote Mine Areas
- The waste rock stockpiles and less contaminated wastes/soils will be capped, minimizing contact with ground and surface water
- Increasing pumping at the Tuttle Shaft to year-round pumping will eliminate the artesian discharge of arsenic contaminated groundwater to the Moira River
- The cleanup activities and year-round pumping at the Tuttle Shaft (together with the cleanup activities in the Industrial Area) are expected to substantially reduce arsenic loading to the Moira River (to approximately less than 1 kg/day)

Cleanup in the Mine Area will provide safe, long-term containment of the remaining wastes/soils in the Main Mine Area, and includes removal of a small quantity of low-level radioactive slag for consolidation with similar wastes in the Industrial Area.

Deloro Mine Site Draft Cleanup Plan -- Tailings Area

The Tailings Area, to the east of the Moira River, was once a natural lowland area. During the ore refining process, ferric hydroxide (red mud) was pumped as waste slurry from the hydrometallurgical plant that operated from 1914 to 1961. The Ministry of the Environment covered this area with a half a metre of crushed limestone in 1986/1987 to eliminate wind and surface water erosion, and to address chemistry related issues. The cover also acts as a shield against low-level radioactivity present in the tailings.

Area: 13 ha

Contaminants of Concern: Arsenic, cobalt, copper, nickel, and low-level radioactive material

Volume of Wastes: Approximately 45,000 m^3

CLEANUP STRATEGY FOR THE TAILINGS AREA

Cover tailings with an engineered soil cover combined with collection/treatment of groundwater and upstream surface water flow diversion.

Overview

Engineered cap

The existing limestone cap in this area will be covered with an engineered cap that is 1.75 metres thick, and vegetated with hybrid poplar trees and grass. These measures will prevent 90 percent of precipitation from infiltrating the tailings.

Ground and surface water management

An interceptor ditch will be built to divert clean, upstream surface water away from the engineered cover.

Water collection/treatment

Contaminated seepage will be pumped and collected for treatment at the Arsenic Treatment Plant.

Design Description

Site Preparation

Site preparation activities will include:

- Preparing access routes,
- Constructing a washpad and mobile washer,
- Installing surface water controls,
- Temporary road construction to the Tailings Area
- Clearing vegetation and trees on the Tailings Area surface and around the perimeter.

Rip Rap and Geotextile

Rock cover material (rip rap) and a manufactured filter (geotextile) will be placed at the toe of the east and west tailings dam walls to provide a seepage collection area. Geotextile will also be installed along the slope of the crushed limestone berm portion of the two dam walls and over the limestone cover of the Tailings Area.

Engineered Cap, and Poplar Tree Plantation

The existing limestone cap will be covered with an engineered cap 1.75 metres thick. The cap will consist of a layer of silty clay loam in combination with topsoil, sand, perforated collection pipe, and compacted clay materials. A geotextile filter will separate the cover soils from the crushed limestone.

The topsoil will provide the initial rooting medium for a hybrid poplar tree plantation, while the silty clay loam and sand will provide the necessary water storage capacity that will increase the effectiveness of the poplar trees. The compacted clay layer will minimize the movement of water into the underlying limestone cover and tailings.

An irrigation system will be installed and operated for a period of about three years while the hybrid poplar tree plantation matures.

Interceptor Ditch

In order to further reduce contact with surface water an interceptor ditch will be built along the north and east side of the Tailings Area. Clean surface water runoff (i.e. stormwater) will be diverted to Young's Creek by the interceptor ditch. Surface water runoff from the capped tailings will be diverted by ditches to low-lying areas south of the Tailings Area. Final surface grading of the Tailings Area will be designed to promote surface water runoff.

Collecting and Treating Contaminated Seepage

Seepage from both the east and west sides of the Tailings Area currently contributes much of the cobalt and copper coming from the site to the Moira River and Young's Creek. A collection and pumping well system will be installed to capture contaminated groundwater and seepage beneath the east and west tailings dams.

Contaminated water will be pumped from the wells to temporary storage tanks. The contaminated water will then be pumped to the equalization pond (i.e. equalization storage basin) for treatment at the Arsenic Treatment Plant (ATP).

The main contaminant of concern from this area is cobalt, although seepage also contains lower concentrations of copper and arsenic. Since the existing ATP can remove dissolved cobalt from contaminated groundwater, the increase in capital, operation, and maintenance costs associated with installing a collection and pumping system for the Tailings Area, is considered good value for the amount of cobalt that will be removed from the environment.

Contaminated seepage and groundwater from the Tailings Area will be pumped to the Arsenic Treatment Plant for four to seven years while the hybrid poplars reach maturity.

Pumping might be phased out in the future when water control measures take effect and reduce the amount of seepage. If the amount of seepage is reduced significantly, but still requires some treatment, a natural wetland treatment system can be installed to provide long-term water quality improvement.

Revegetation

Following completion of the cleanup, the Tailings Area will be landscaped and seeded with a mixture of grasses to stabilize the surface and limit erosion until the hybrid poplar tree plantation is firmly established.

Key performance indicators

The draft cleanup strategy for the Tailings Area is expected to achieve the following:

- The engineered cover and hybrid poplar trees will allow less than 10 percent of the annual precipitation to infiltrate to the underlying tailings, thereby minimizing contaminated seepage beneath the walls of the tailings dams.
- The interceptor ditch will divert clean surface water from upstream of the Tailings Area, further reducing contact with surface water.
- The cleanup measures will reduce the discharge of cobalt and copper from the Tailings Area to the Moira River.

Cleanup of the Tailings Area will provide safe, long-term containment of the tailings, including low-level radioactive materials.

Deloro Mine Site Draft Cleanup Plan -- Young's Creek Area

Young's Creek begins on the Deloro Mine Site at its northeast corner and flows south along the eastern side of the Tailings Area, connecting with the Moira River south of Highway #7.

Over the last century, run-off from the Tailings Area has resulted in heavy sediment contamination in the creek. Water flow is very low in this area, which is typically wetland-like in nature. Young's Creek currently contributes about three percent of the arsenic loading to the Moira River watershed.

Cleanup of this area is planned due to the high levels of metals in sediments, the presence of low-level radioactive material in the onsite portion, and due to the potential for occasional high river flows to re-suspend contamination, especially during a 100-year flood event. Biological diversity and abundance in this area are affected as a direct result of contaminated sediments.

The Young's Creek Area is part of a provincially significant wetland, known as the Deloro Wetland Complex. In light of that fact, a wetland restoration plan will be implemented following removal of contaminated sediments.

Area: Onsite – about 47 hectares (ha)
Offsite (south of Highway # 7) – about 19 ha

Contaminants of Concern:

Onsite area -- Arsenic, cobalt, copper, nickel, and low-level radioactive material

Offsite area -- Arsenic, cobalt, copper, and nickel. There is no radioactivity in the offsite area.

Volume of Wastes:

Onsite -- 100,000 cubic metres (m^3) of shallow contaminated sediments and about the same amount of contaminated deeper soils

Offsite -- About 68,000 m^3 of contaminated shallow sediments

CLEANUP STRATEGY FOR THE YOUNG'S CREEK AREA

Full depth excavation of onsite sediment, shallow depth excavation of offsite sediment, and disposal in a new onsite engineered containment cell followed by creek rehabilitation.

Overview

The Young's Creek Area includes an onsite and an offsite portion. The onsite portion is much more contaminated, and to a greater depth than the offsite portion.

Excavation and containment

Contaminated sediments and soils will be excavated, dewatered, and placed in a secure engineered containment cell that will be built onsite to the south of the Tailings Area.

The containment cell will have an engineered vegetated cap and liner system to isolate contamination from the environment. The cell will be substantial in size, covering an area of about 5 hectares (ha) to a height of approximately 17 metres.

Wetland reconstruction

Areas of the wetland removed by excavation will be reconstructed. This is especially important for rebuilding the ecosystem since this area is part of a provincially significant wetland.

Design Description

Site Preparation

Site preparation work will include:

- Mobilization of equipment (excavators, trucks, dewatering pumps and equipment, site trailers),
- Construction of access roads, and establishing temporary services,
- Draining any ponded water to allow excavation work to be done in the "dry"
- Sediment control measures will be implemented to minimize the transport of disturbed sediment from Young's Creek to the Moira River.

Excavation and Containment

Construction of Staging Areas

Before excavating contaminated sediment/soil, temporary storage areas (known as staging areas) will be constructed. To build the staging areas, a manufactured filter (geotextile) will be placed on the ground. It will be covered with 300 mm of crushed rock. Another manufactured filter (geotextile) will be placed on top, and 150 mm of gravel (granular A) added to that.

Two separate staging areas will be required, one for the onsite portion and one for the offsite portion of Young's Creek. The staging areas will provide a stable work platform where wet contaminated sediment/soil can be dewatered prior to placement in the secure containment cell. Clay diversion dams will be built to isolate the staging areas from potential flood waters.

Dewatering Excavated Materials

Contaminated sediment and soil will be dewatered before being placed in the onsite containment cell. Dewatering will occur in the onsite and offsite staging areas. Excavated contaminated sediment and soil will be dewatered by placing the wet material in rows, approximately 1.5 m in height and 4 m in width. Rows will be placed parallel, and will be spaced approximately 4 m apart to allow an excavator to travel between them. The excavator will move between the rows and turn over the wet sediment/soil to promote dewatering and drying. Rows will, in sequence, be moved closer to the stockpile location.

After five turnover/movements, the sediment and soil should be dry enough to place into the dewatered material stockpile. Bulldozers will be used to create a ramped stockpile that will be about 5 m in height. The material stockpiles will eventually be loaded onto trucks for storage in the secure onsite containment cell.

The onsite and offsite staging areas will have an approximate area of 12,000 m^2. The onsite and offsite staging areas will allow sediment/soil to be dewatered at a rate of approximately 1,000 m^3/day. These dewatering rates result in approximately 200 excavation days and 70 excavation days respectively, required for the onsite and offsite portions of Young's Creek.

Silt Curtains and Sedimentation Basins

Silt control fencing will be placed along the perimeter of each staging area to prevent the movement of sediment/soil to the Young's Creek Basin.

As backup to the silt control fencing, two sedimentation settling basins will be created in the onsite and offsite portions of Young's Creek. The sedimentation basins will allow suspended sediment to settle out, and will prevent them from going into the river. The sedimentation basin for the onsite portion of Young's Creek will be created north of Highway # 7.

For the offsite portion of Young's Creek, a sedimentation basin will be created in the southern portion of the Southern Pond. Suspended sediment that accumulates in the sedimentation basins will be removed and placed in the secure onsite containment cell.

For the small portion of the creek between Old Marmora Road and the Moira River, sedimentation controls such as manufactured filter (geotextile) silt fencing, sand bags, and/or straw bales will be used. This portion of the creek will be excavated during a low-flow period to minimize the movement of suspended sediment to the Moira River.

Temporary Diversion Dams

Once the staging areas and sedimentation basins are in place, temporary diversion dams and ditches will be used to isolate sections of the Young's Creek Basin. The temporary diversion dams will allow flow through the Young's Creek Basin at all times during the work. Excavation activities will proceed in the downstream direction to prevent recontamination of remediated areas. The diversion dams will divert surface water flows around the active excavation area and will allow excavation work to proceed in the "dry".

The diversion dams will have a base width of approximately 8 m, a top width of 1 m, and a height of 2 m above the existing creek bed. The elevation of the top of the diversion dam will be

approximately 0.5 m higher than the flood water level to control flooding. The dams will be constructed with a clay core and covered with a layer of cover material (rip rap) to prevent erosion.

After the diversion dams are in place, water will be pumped out into the adjacent portions of the creek. After the water has been removed, contaminated sediment will be excavated, loaded, and transported to the staging areas using six-wheel drive articulating dump trucks. The use of these six-wheel drive vehicles will allow transport of contaminated sediment/soil from the excavation site directly to the staging areas without having to leave the Young's Creek Basin.

Crushed granular rock will be placed within portions of the dewatered ponds of the Young's Creek Basin, to create a temporary haul road from each excavation site to the staging area. This crushed granular rock will be removed and reused following the completion of a given sector.

Following dewatering the sediment/soil will be loaded and transported to the secure onsite containment cell.

Once excavation activities are completed, the gravel (granular A) used to construct the staging area will be removed and disposed in the secure onsite containment cell. The crushed stone underlying the gravel will be removed and stockpiled for future onsite re-use. Contaminated sediment/soil underlying the staging pads will be excavated and transported directly to the secure onsite containment cell. Dewatering of the sediment/soil will occur in the containment cell. The leachate from this dewatering will be collected by the leachate collection system.

Dewatered sediment/soil will be loaded onto trucks and transported to the onsite containment cell. For the onsite portion of the excavation work, trucks will use the existing access road that runs parallel to the onsite portion of Young's Creek. No offsite transport of contaminated sediment will be required for the onsite portion of Young's Creek. Temporary access roads are not required in the onsite portion of Young's Creek.

Temporary Access Roads

For excavation work in the offsite portion of Young's Creek, temporary access roads will be built between the ponds to allow movement of contaminated sediment from the Central and Southern Ponds to the staging area in the Northern Pond.

The access roads will be approximately 5 m in width. Material used to construct the temporary access roads include a non-woven geotextile placed on the sub-grade, 300 mm of compacted gravel (granular B), followed by 150 mm of compacted gravel (granular A). Crushed granular rock will be used to create temporary haul roads within portions of the dewatered ponds.

Following dewatering and stockpiling in the staging area, the contaminated sediment will be transported to the onsite containment cell. The transport trucks will be required to cross Highway # 7. The trucks will then use the access road that runs parallel and to the west of the onsite portion of Young's Creek to access the onsite containment cell.

Containment Cell Liner System Construction

Excavated sediment/soil will be placed in an engineered secure onsite containment cell to be built south of the Tailings Area. The proposed containment cell will be located about 200 m

south of the existing Tailings Area and approximately 600 m north of Highway # 7. The footprint of the cell covers approximately 5 ha and will rise approximately 17 m above the existing Young's Creek bed. The containment cell will provide a capacity of approximately 270,000 m^3 for contaminated sediments.

The containment cell will have an engineered cap and liner systems that will be designed to prevent contaminant releases. The cap will consist of a vegetated cover, 150 mm of topsoil, 1,000 mm of compacted fill, over a geotextile, a 300-mm cap drainage layer of crushed granular material, and a manufactured (geosynthetic) clay liner within a 500-mm sand cushion and sand grading layer to prevent infiltration of surface water. The cap will be designed to promote runoff and water uptake by plants, thereby reducing the amount of precipitation that could come into contact with the contaminated sediment/soil in the containment cell.

The cap includes a drainage system to intercept any water that does not run off or is not absorbed by roots before it contacts the stored sediment/soil. This clean infiltrating water collected in the cap system will be directed to Young's Creek. The thickness of the cap will also reduce low-level radiation fields associated with some of the radioactive sediments to background.

The base liner system will consist of 1,000-mm thick composite clay and a thick plastic liner with a leachate collection system embedded in a 300-mm granular drainage layer to collect any water that does happen to penetrate the cap system. The liquid collected by the leachate collection system will be collected in sumps and stored in a holding tank that will be pumped and transported to the Arsenic Treatment Plant in the Industrial Area. The containment cell will be located above the water table to prevent groundwater contact with stored sediment/soil.

Creek Rehabilitation, Engineered Wetland

Following excavation of contaminated sediment and soil, the area will be graded to provide a wetland shelf around the perimeter of the ponded areas, to re-establish the wetland environment.

The shelf will be graded to provide a water depth (approximately 300 mm) to support a diverse wetland community associated with marsh habitat. The shelf will be continuous around the perimeter and have varying widths of plus or minus 3 m based on both aesthetic and Ministry of Natural Resources (MNR) requirements.

A 75-mm to 100-mm layer of topsoil will be placed on top of the wetland shelf to provide an ideal environment for seed germination and root development. The shelf will provide limited treatment potential, but will stabilize the soil and provide an aesthetic function. The perimeter shelf will create an ideal environment for the natural revegetation to occur.

A series of wetland planting cells will be built at locations throughout the wetland perimeter shelf. The wetland planting cell will be approximately 10-m by 10-m in area. The plant mix will consist of seed and potted plant stock. It will include native shrubs, sedges, rushes, and grasses. For every kilometre of creek bank, three planting cells will be built.

Two constructed wetland parcels will provide water quality improvements. One wetland parcel will be located onsite at the southern extent of the remediated area just upstream of Highway # 7. The offsite parcel will be located just upstream of the point of discharge into the Moira River.

The wetland parcels will provide some level of treatment and filtration prior to the discharge of creek water into the Southern Pond and the Moira River.

Key performance indicators

The draft cleanup strategy for the Young's Creek Area will achieve the following:

- Removal of the contaminated sediments/soils, including the low-level radioactive sediments that originated from the Tailings Area will address the following issues:
  - Exposure to radiation
  - Elevated human health and ecological risk
  - Potential erosion/transport of contaminated materials downstream during severe storm events/acts of nature
  - Undesirable risk to people and the environment in the offsite portion of Young's Creek

The secure containment cell will provide safe, long-term storage of these materials, including the radioactive tailings/sediments.

Deloro Mine Site Cleanup Project -- Next Steps

2004

Public Consultation on the Draft Proposed Cleanup Plan

The Ministry of the Environment is committed to public consultation on the draft cleanup plan. On June 15, 2004, the ministry initiated consultation with the two technical committees for the Deloro Mine Site Cleanup Project (the Technical Liaison Committee, and the MOE Technical Committee). On July 21, 2004, the ministry broadened that consultation to include the Public Liaison Committee. CH2MHILL's draft proposed cleanup plan was presented to the Deloro Mine Site Cleanup Project's three project liaison committees at a joint workshop on July 21, 2004. Members of these committees were given the first opportunity to review the cleanup plan and provide comments. Those comments have been considered and incorporated where possible.

The ministry invites residents of Deloro, residents downstream of the site, local municipalities, environmental groups, and anyone with an interest in the project to review the draft cleanup plan for the Deloro Mine Site. Comments will be recorded, and reviewed. A summary of comments and responses to those comments will be provided as a record of consultation. Once consultation is complete, the ministry and its consultants will finalize the cleanup plan. The 60-day comment period will close on January 12, 2005.

For more detailed technical background information a CD, containing the full technical report of the draft cleanup plan, the rehabilitation alternatives and closure plans for each area of the mine site, is available for reference.

How to Access Reports

The technical reports used in the development of the draft cleanup plan, are available for viewing at ministry offices in Kingston, Belleville and Peterborough; the Deloro Village Library; the Municipality of Marmora and Lake; the Municipality of Centre Hastings; Quinte Conservation;

the ministry's Environmental Assessment and Approvals Branch (Approvals, Public Record File and Environmental Clean-up Fund), Toronto; the Ontario Clean Water Agency, Deloro; the Ministry of Northern Development and Mines, Sudbury; and the Ontario Legislative Library, Toronto. The Alternatives Reports, Closure Plans for each of the four areas of the mine site, and the full technical draft Integrated Cleanup Plan are available for downloading from the ministry's Web site at http://www.ene.gov.on.ca/envision/deloro/index.htm.

Public Information Session – November 23, 2004

To further explain the details of the cleanup plan, a public information session will be offered at the Deloro Community Centre on November 23, 2004. There will be two sessions, one from 1 – 5 pm, and an evening session from 7 pm – 10 pm.

Optional Workshop – November 29, 2004

For those who would like an additional opportunity to discuss and provide feedback on the draft cleanup plan, the ministry will offer a registered workshop on November 29, 2004 at the Deloro Community Centre. The workshop will only be held if there is sufficient community interest. If you are interested in participating in this workshop, please register in advance by calling Heather Hawthorne, Communications Advisor, 613-549-4000 extension 6927.

Please provide your comments in writing no later than January 12, 2005 to:

Deloro Mine Site Cleanup Project
Ministry of the Environment
133 Dalton Avenue
Kingston, Ontario
K7L 4X6

2005

Finalize the cleanup plan: The ministry will finalize the cleanup plan following public consultation.

Detailed engineering design: Development of the 'blueprints' for engineered facilities, covers, caps, wells and pumping stations.

Licence applications and permits: Regulatory approvals that must be obtained in order to proceed with construction, including permits from: the Ministry of the Environment (MOE), Conservation Authority (CA), Ministry of Natural Resources (MNR), Department of Fisheries and Oceans (DFO), Canadian Nuclear Safety Commission (CNSC), and the Ministry of Northern Development and Mines (MNDM) among others.

Federal Environmental Assessment Requirements: Required as part of the ministry's application to the Canadian Nuclear Safety Commission (CNSC) for a licence for the long-term storage of the existing low-level radioactive material at the site.

2006

Tendering: Offering construction contracts for cleanup work through a competitive bid process.

Site preparation construction: Preparation of the site for major cleanup construction activities will involve construction of access roads and wash-down facilities, clearing vegetation and trees, and installation of surface water controls.

2007 - 2012

Complete the cleanup: Major cleanup construction begins. All materials will be secured to make the site safe for people and the environment for hundreds of years.

Long-Term Commitment

The Ministry of the Environment will maintain its long-term commitment to this site. The site will require ongoing monitoring of surface water, groundwater, pumping systems, and the wastewater treatment plant to ensure the continued effectiveness of the site cleanup measures.

Estimated Cost of Site Cleanup

The total estimated capital cost to complete the cleanup is $30 – 40 million with annual operation, maintenance, and monitoring costs of approximately $1,124,000.

This cost estimate will be further refined once the draft cleanup plan has been finalized and the detailed design work completed.

Long-term funding for the project will continue to be made available through the ministry's Environmental Cleanup Fund. The Province of Ontario is committed to this project, and will finish the cleanup to ensure the site is safe for people and the environment for hundreds of years.

Appendix A – Illustrations

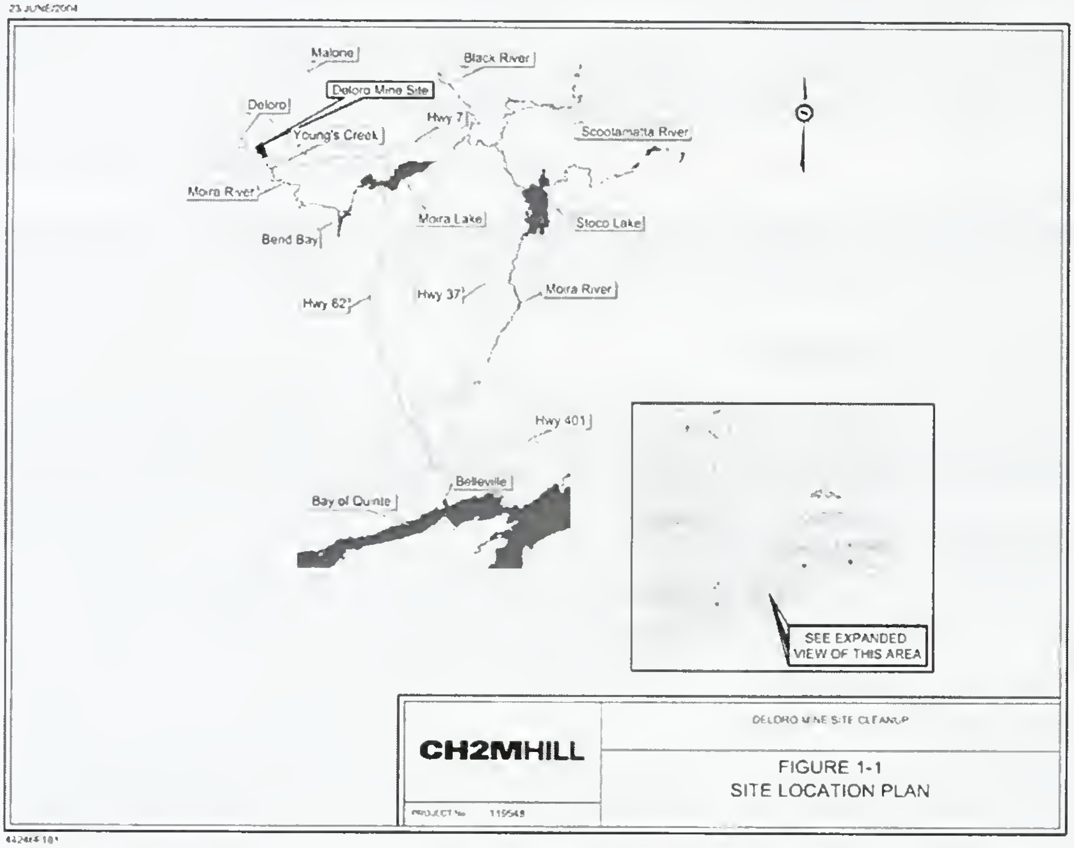
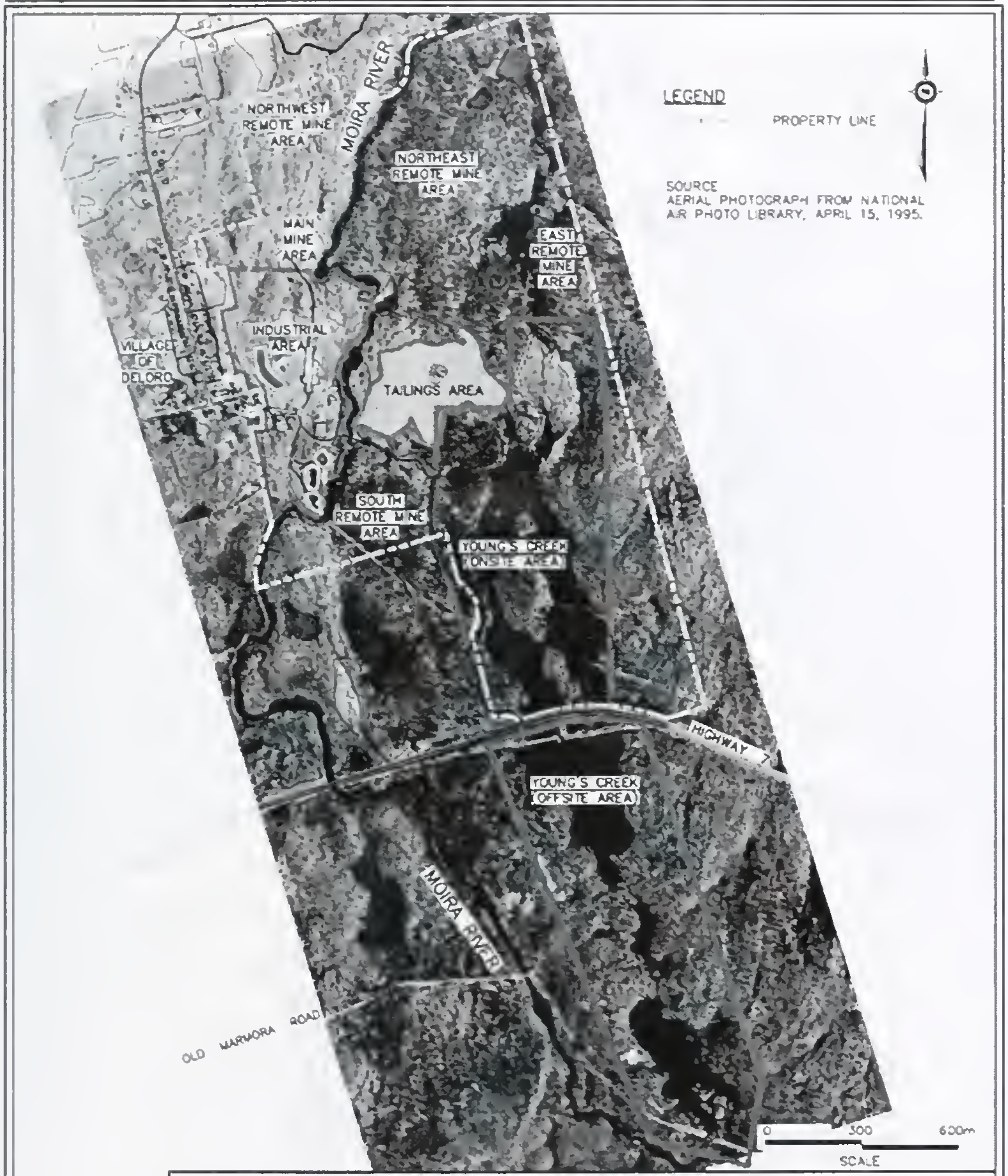


FIGURE 1-1
SITE LOCATION PLAN

Deloro Mine Site – Division of Areas



CH2MHILL

DELORO MINE SITE CLEANUP

FIGURE 1-3: DELORO MINE/REFINERY SITE SHOWING THE INDUSTRIAL, MINE, TAILINGS AND YOUNG'S CREEK AREAS - DELORO, ONTARIO

PROJECT No. 119548

44246F99E

Overview, Industrial Area

03/AUG/2004

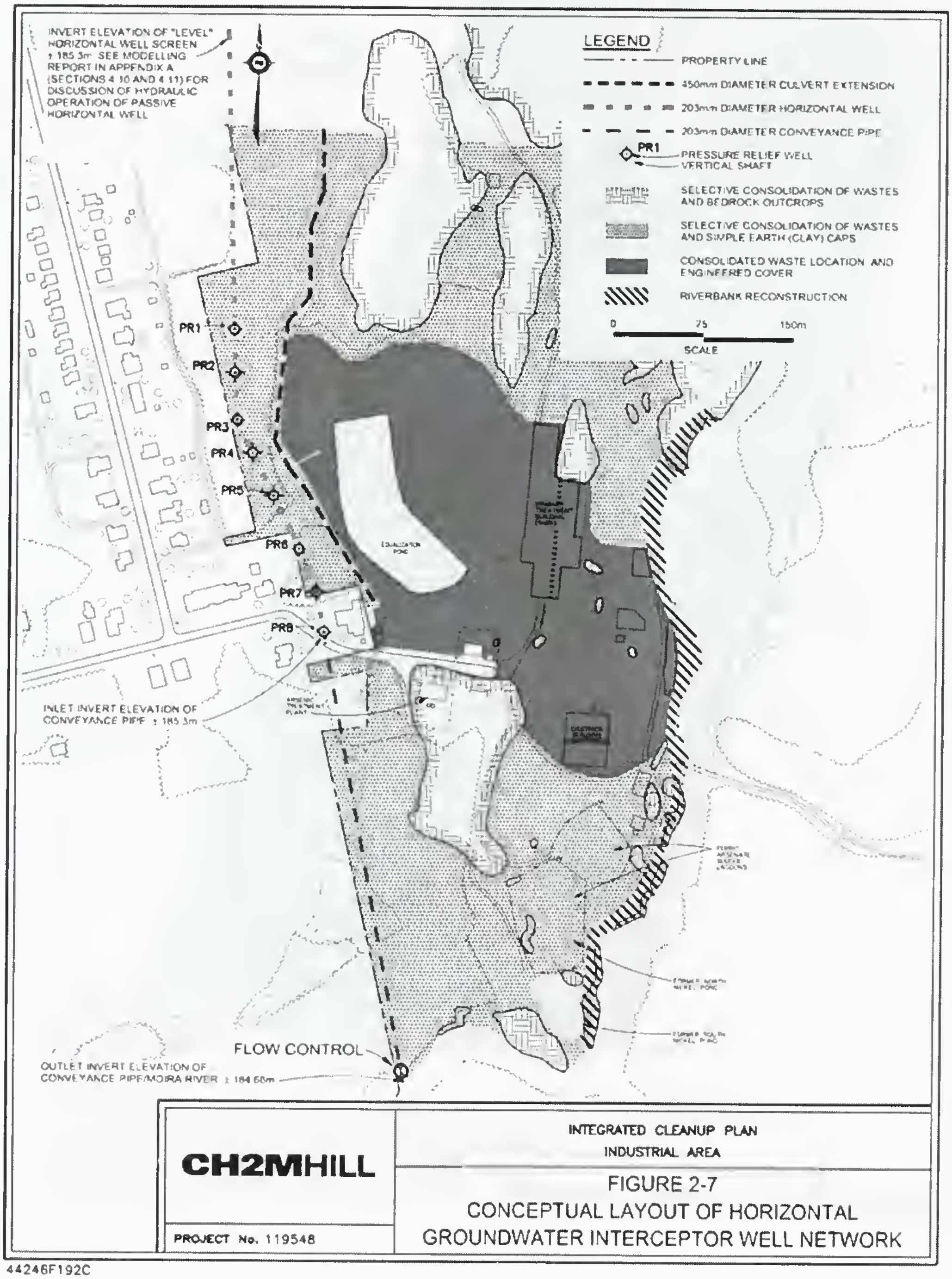
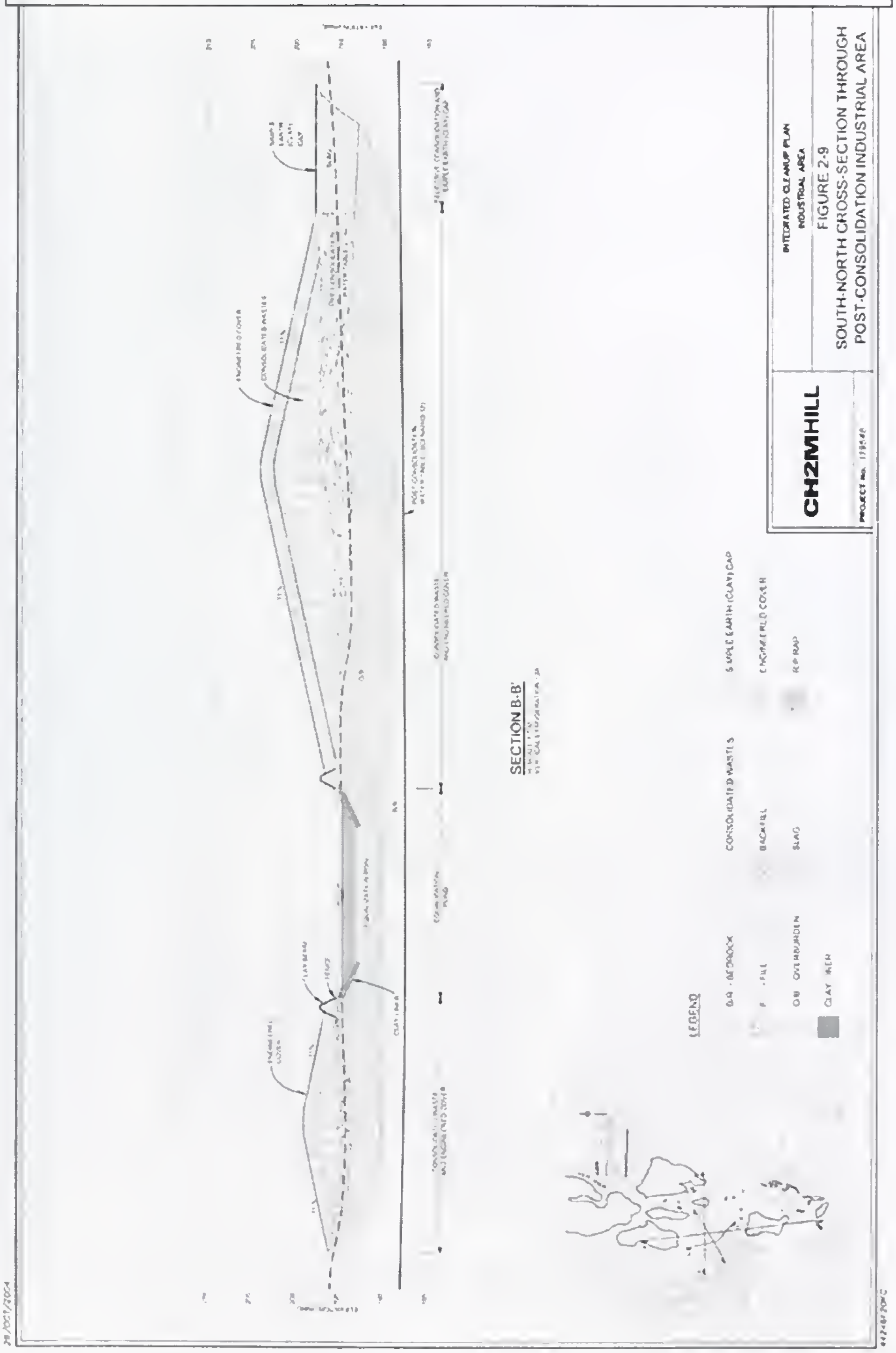


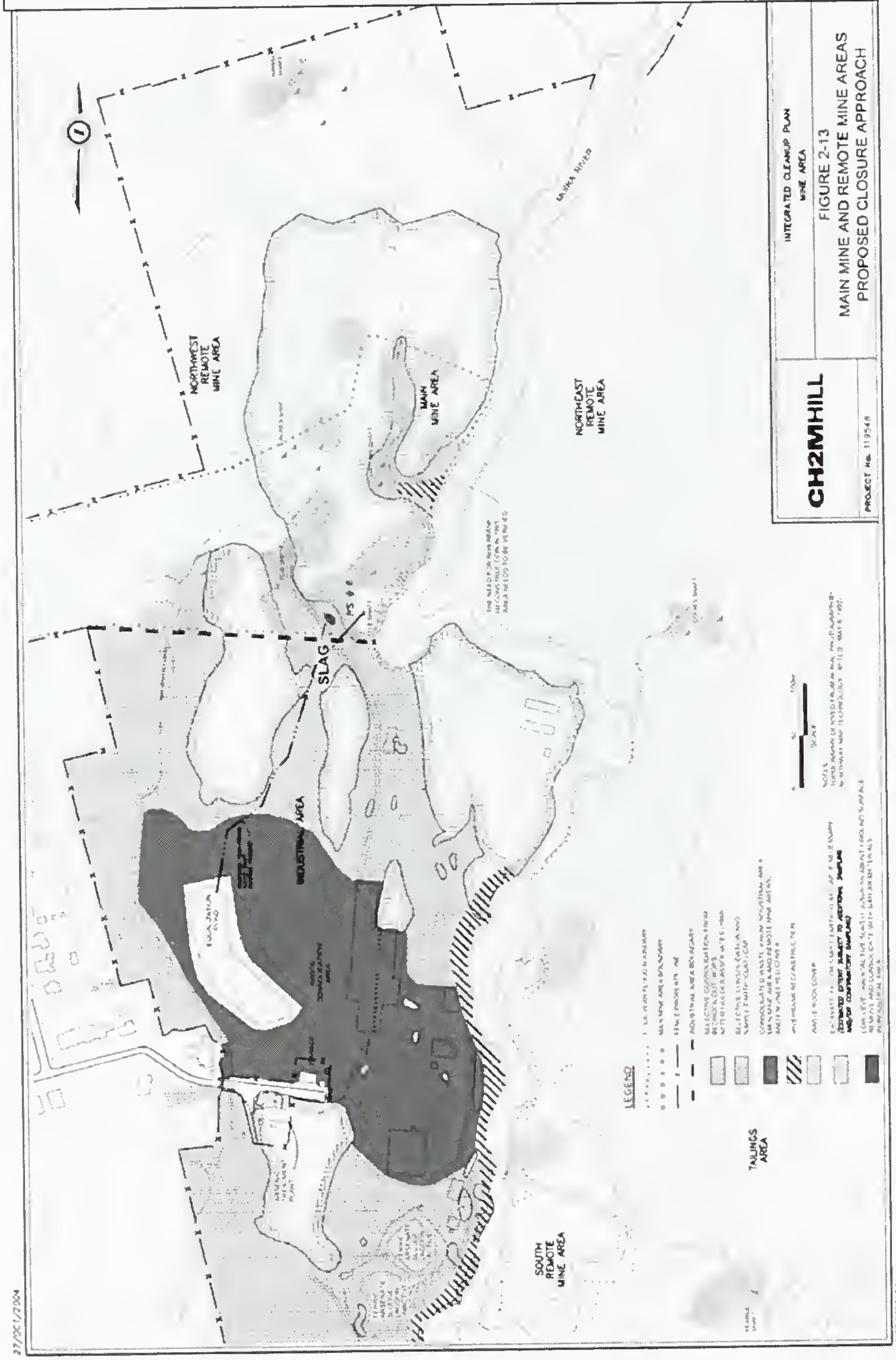
FIGURE 2-7
CONCEPTUAL LAYOUT OF HORIZONTAL GROUNDWATER INTERCEPTOR WELL NETWORK

44246F192C

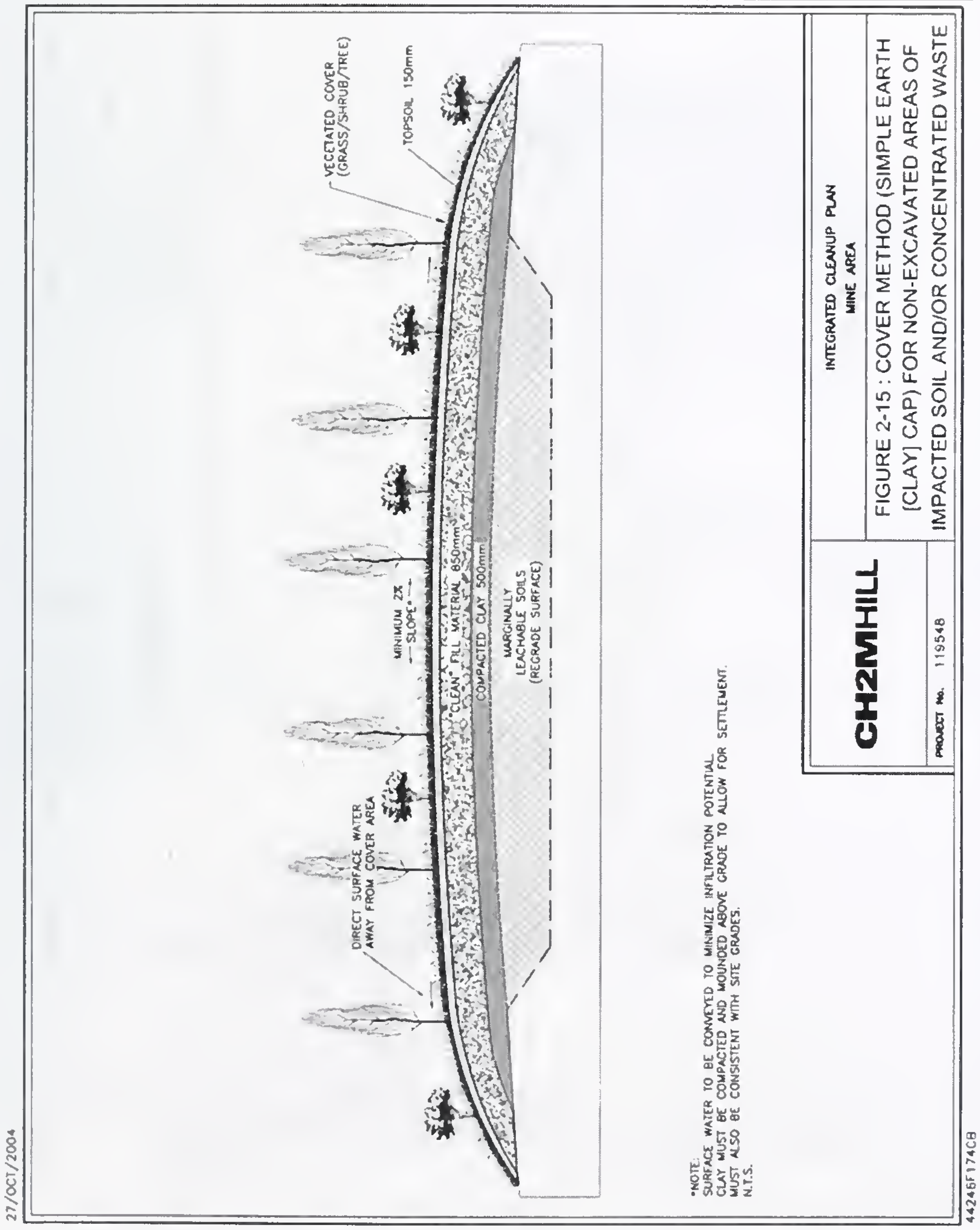
Cross-section of Engineered Cover, Industrial Area



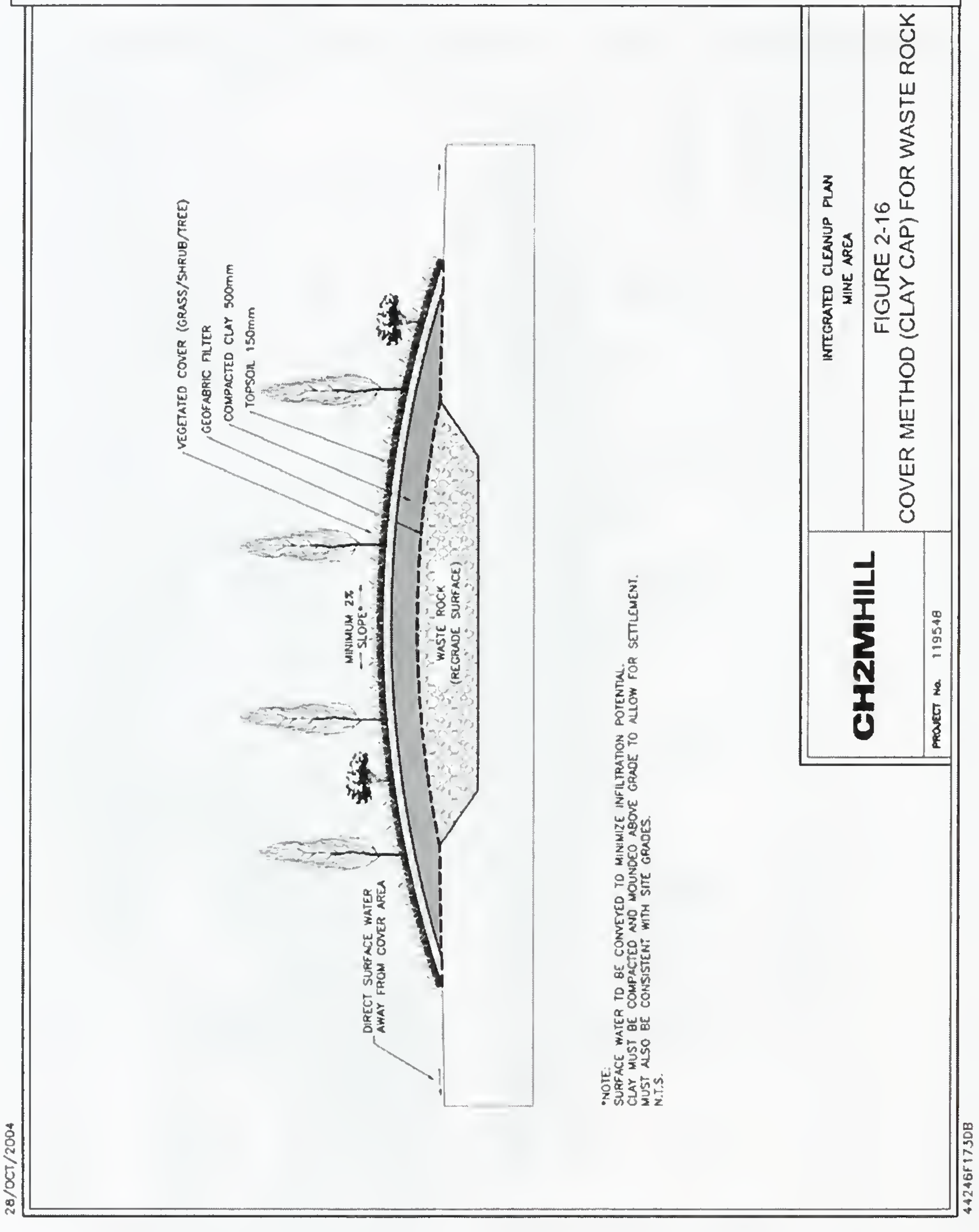
Overview, Mine Area



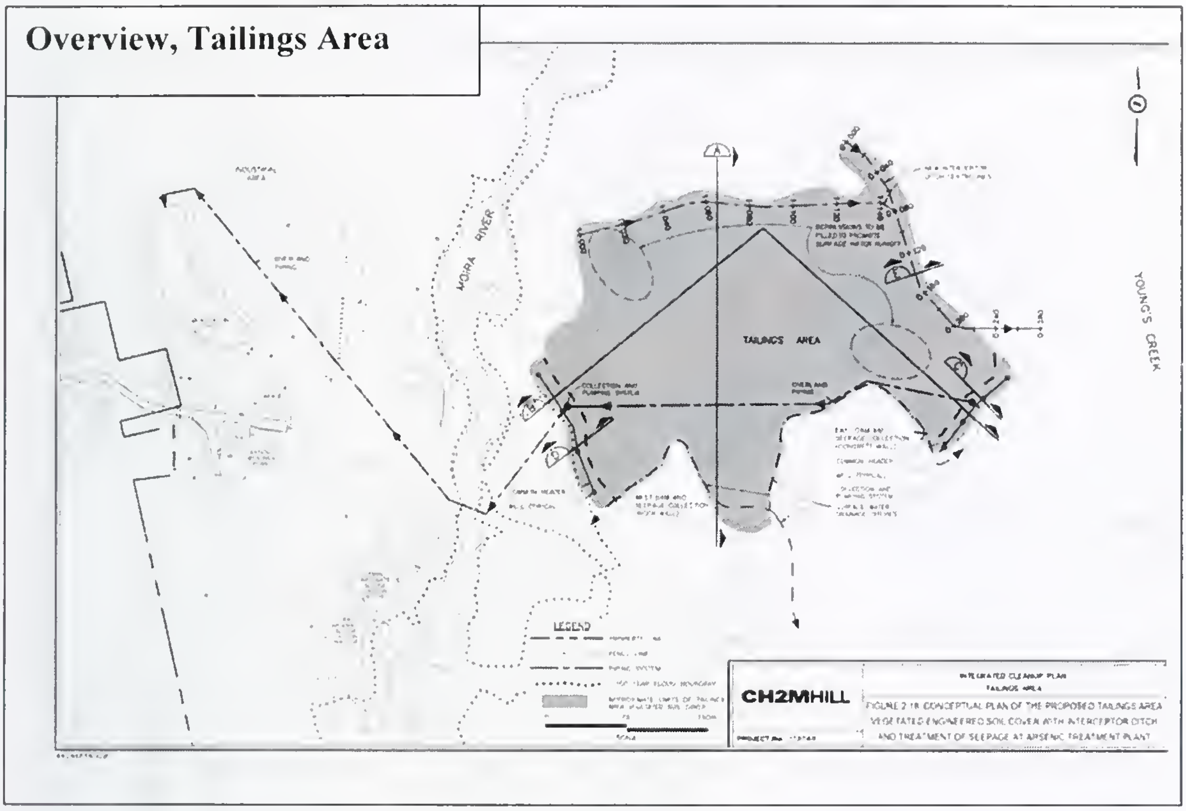
Cross-section of Engineered Clay Cap, Mine Area



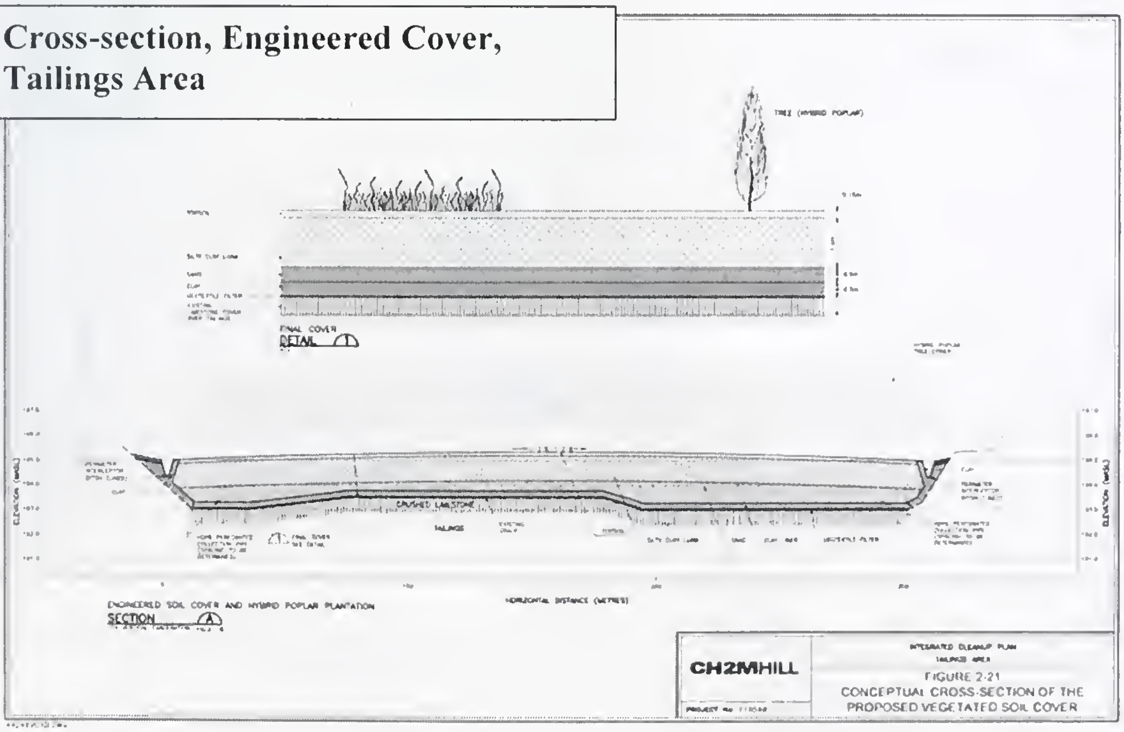
Cross-section of Engineered Clay Cap, Mine Area



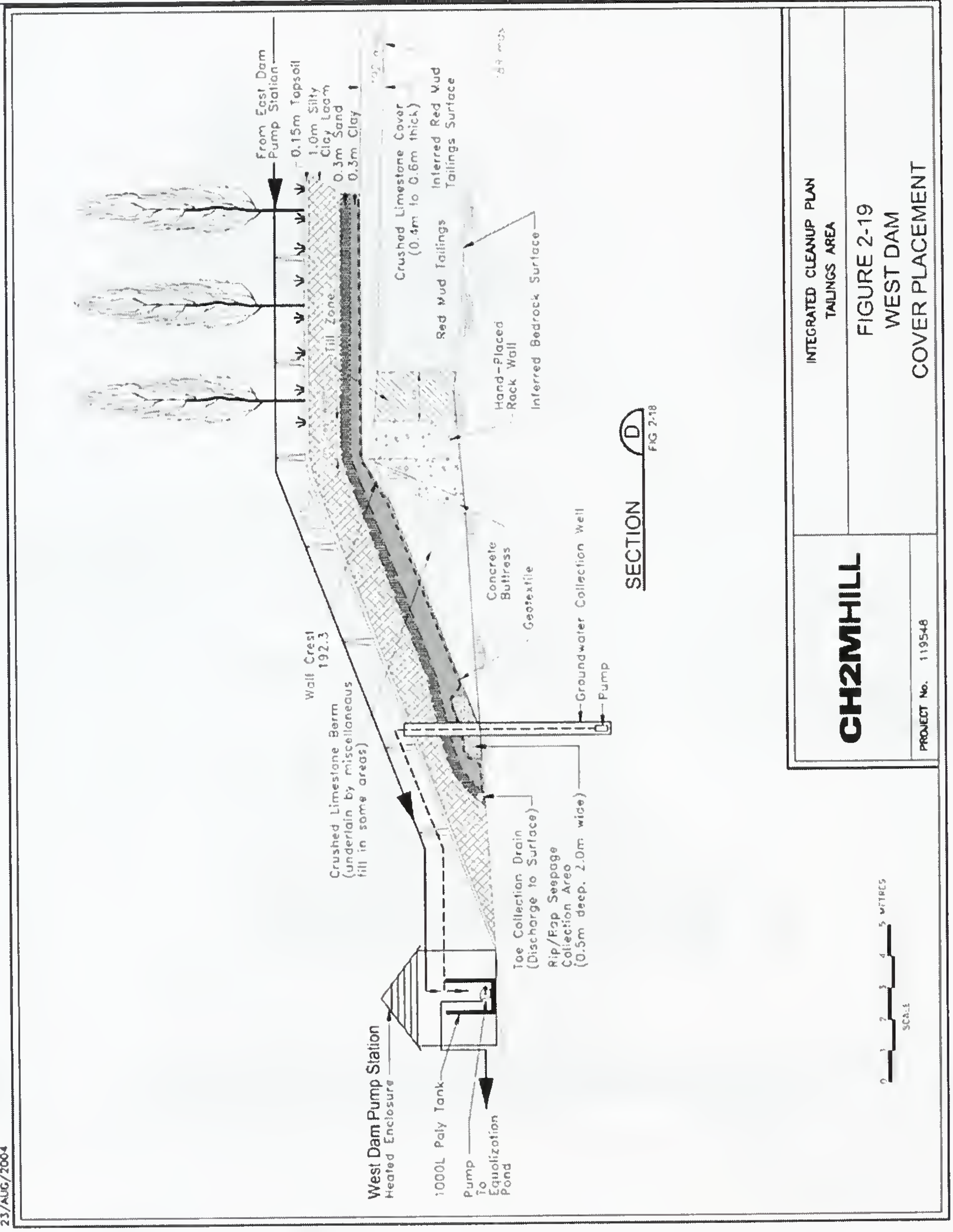
Overview, Tailings Area



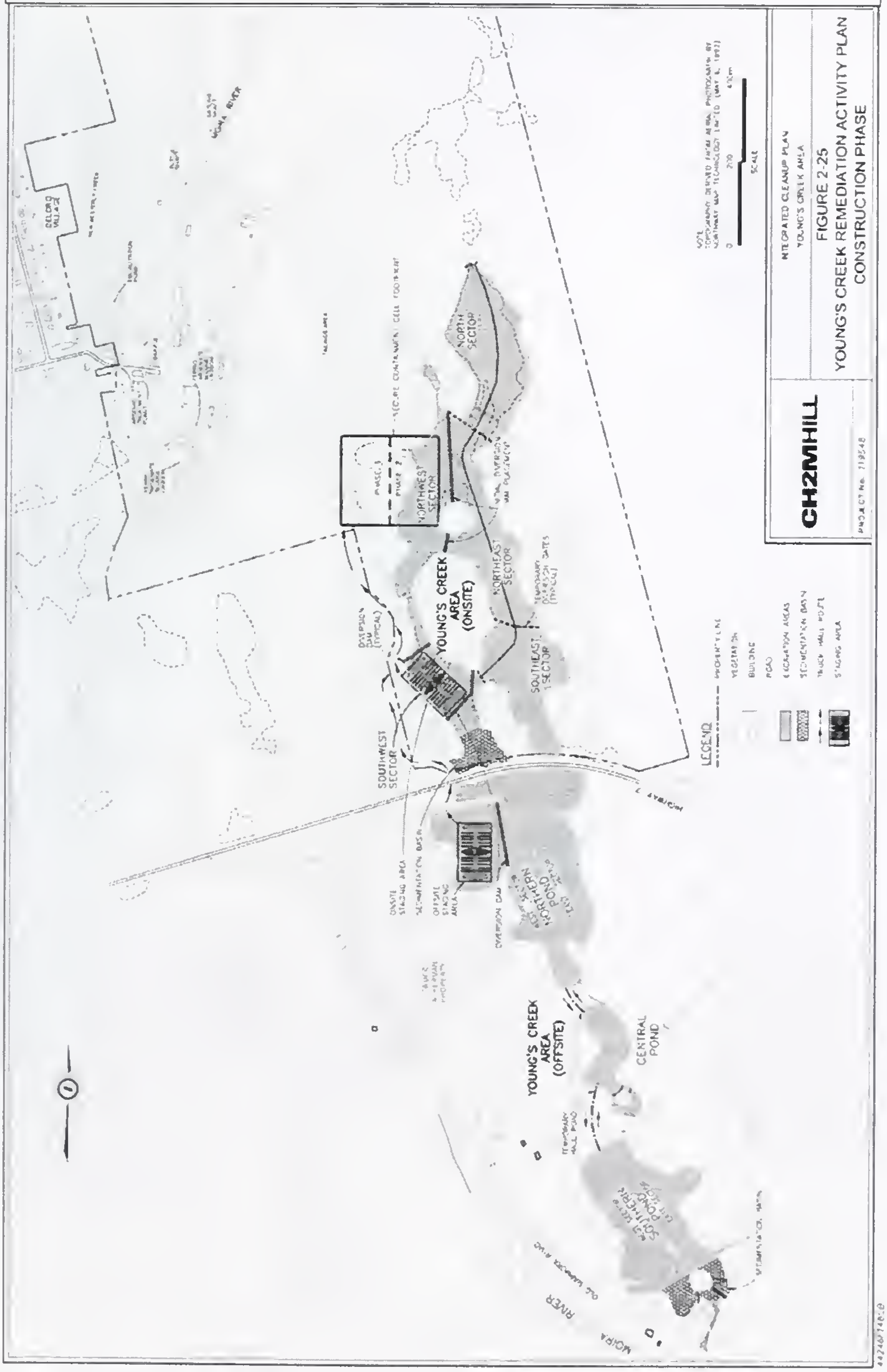
Cross-section, Engineered Cover, Tailings Area



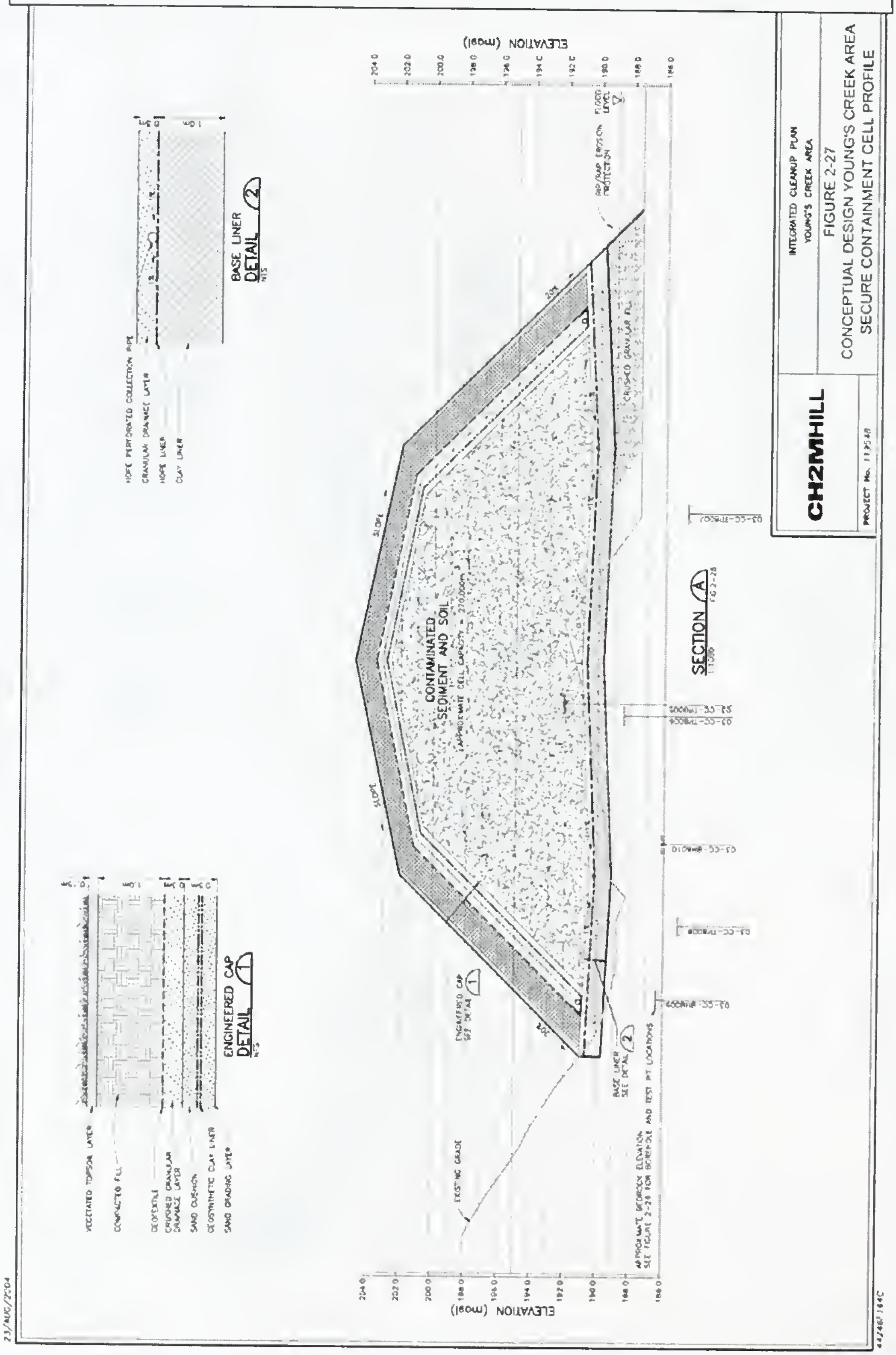
Cross-section, Engineered Cover, Tailings Area



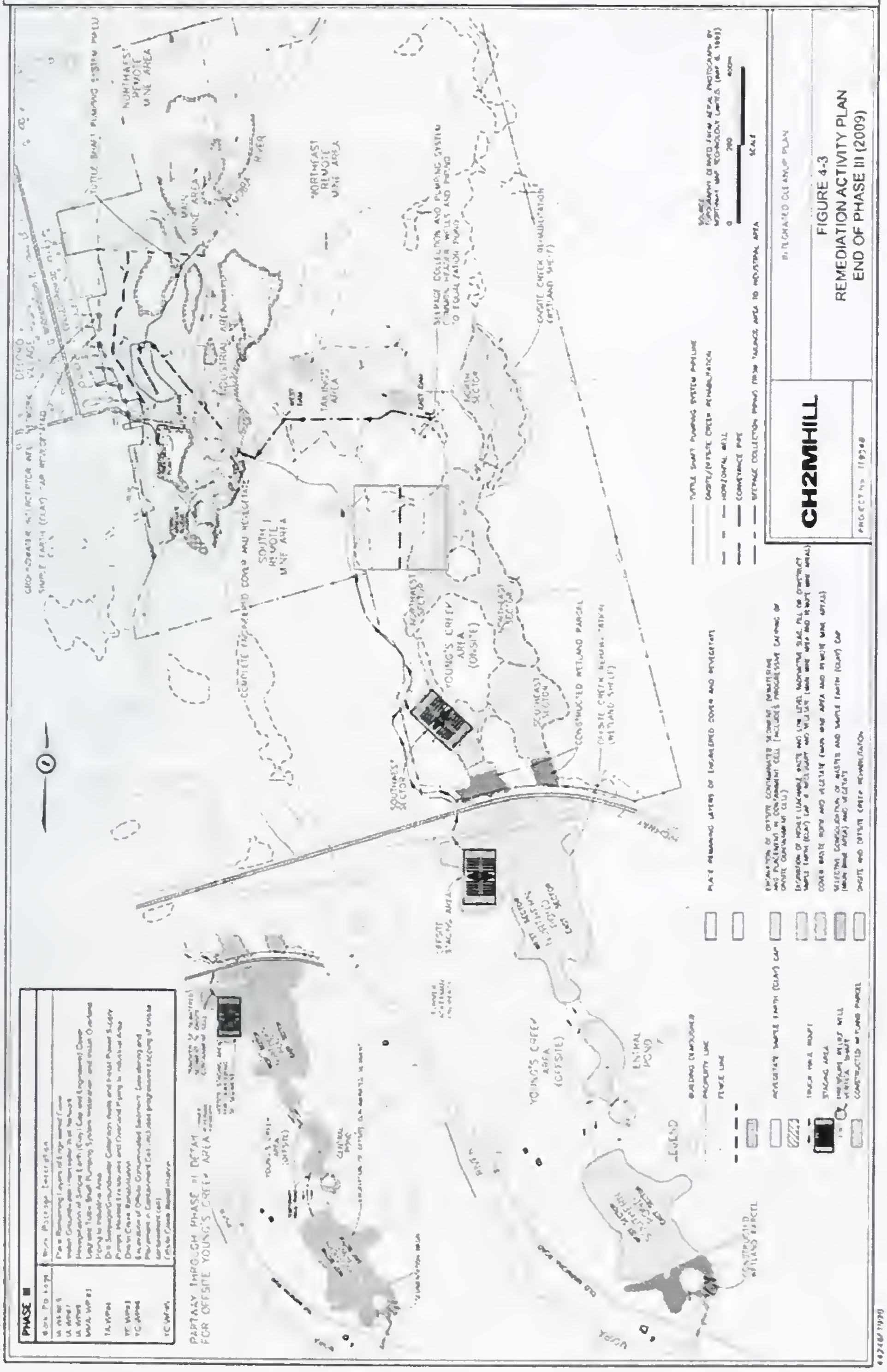
Overview, Young's Creek Area



Cross-section, Engineered Containment Cell, Young's Creek Area



Overview of Deloro Mine Site Post-Cleanup



Appendix B -- Health, Safety and Environmental Controls

Protection of public health and the environment is of paramount concern throughout the proposed cleanup of the Deloro Mine Site. Public health includes worker health and protection for individuals engaged in the cleanup activities, as well as protection for residents near the site. This includes people living in the Village of Deloro and downstream along the Moira River.

Environmental protection includes identifying risks related to potential releases during the cleanup whether through liquid releases to the Moira River, spillage of wastes during relocation, or dust/air emissions as a result of physical work at the site. The draft Integrated Cleanup Plan outlines the provisions that are proposed as part of this comprehensive plan. This includes provisions for containment, monitoring, and mitigation. A number of specific plans are proposed to address various aspects of the identified health, safety, and environmental risks.

Health and Safety - Prior to the implementation of the cleanup plan, an Environmental and Community Health Protection Plan will be developed. This plan will include measures to control dust, noise, odours, surface water runoff, surface water run-on, and erosion, as well as the use of appropriate equipment and personnel decontamination procedures.

Site Security and Safety - At present, the Deloro Mine Site and the Ontario Clean Water Agency (OCWA) compound are completely enclosed by a 7,606 m perimeter fence installed in March 2000. The majority of the chain link perimeter fence was installed to a height of 2.13 m, including 0.30 m of barbed wire. Adjacent to Highway # 7, the perimeter fence was installed to a height of 2.13 to 2.44 m, without barbed wire to satisfy Ministry of Transportation's Permit requirements.

There are seven points of entry to the site, mainly along the southern and western property boundaries, including four 9.0-m wide gates, one 6.0-m wide gate, one 1.2-m wide gate, and one recently installed gate near Highway # 7 to facilitate the installation of monitoring wells adjacent to Young's Creek. Access gates will remain closed if not in use during the day, and all gates will be closed and locked at the end of each working day to prevent public access to the site during remediation activities.

Access to the Industrial Area and portions of the Mine Area, along the west side of the Moira River, will be through the main site access gate near the Arsenic Treatment Plant. The existing onsite access road will be used for construction vehicles to access these areas.

Access to the Tailings Area and Young's Creek Area onsite will be via the access road off Highway # 7. Prior to work being conducted in the offsite portion of Young's Creek, a 1.8-m high chain link fence will be installed around the perimeter of the offsite portion of Young's Creek near key access points (i.e. road areas or other areas where a higher potential for public access exists). In other more remote and inaccessible areas, it will be determined during the final remedial design if temporary fencing is sufficient or required to further restrict public access to the work area. Any temporary perimeter security fencing erected during the implementation of the project will be removed.

Warning Signs - A group of three signs are affixed to the existing fence at distances varying between 50 m and 200 m, which read as follows:

- *Danger, No Trespassing, Positively No Admittance* (25 cm by 36 cm)
- *Caution, Radiation Area, Radioactive Materials, Authorized Personnel Only* (25 cm by 36 cm)
- *Mine Hazard Area, Danger: Every person who alters, impairs, or destroys this notice, this fence or any rehabilitation work made in accordance with Part VIII of the Mining Act, is guilty of an offence and, upon conviction, is liable to a fine of not more than $30,000* (30 cm by 30 cm)

During the construction phase of the project, signs will be used to caution the public along Highway # 7, in the Village of Deloro, and at site entrances. Signage may include "*Trucks Turning*" and other construction warning signs, as well as "*Danger – Access By Permit Only*" at access gates. Additionally, flagmen may be needed along Highway # 7 to control traffic when heavy machinery or large transport trucks enter or exit the highway.

Institutional Controls - Institutional controls at the site are as follows:

- Fencing exists on the perimeter of the Deloro Mine Site and access is restricted to authorized personnel.
- Signage exists on the perimeter fence as well as at the north and south approaches along the Moira River.
- The ministry will retain ownership and control of the site for the foreseeable future.
- Site conditions will be registered on title at the conclusion of the cleanup coincident with the issuance of a Record of Site Condition (RSC).

Noise Levels - To minimize the impact of potentially elevated sound levels on the local population, working hours will be scheduled to respect municipal by-laws regulating such activities. It is expected that sound levels will return to pre-construction conditions following the completion of the rehabilitation work.

For More Information on Health and Safety Issues - For more detailed information on health and safety considerations and plans, including the Environmental and Community Health Protection Plan, dust control and air monitoring, noise control, surface water protection, emergency preparedness, contamination control and other operational procedures, please refer to the *Deloro Mine Site Cleanup – Integrated Cleanup Plan, Draft Report*.

Monitoring Program - A comprehensive monitoring plan will be required to evaluate the effectiveness of the cleanup measures and to identify the need for maintenance tasks. The physical and chemical stability, water quality, and biological features at the Deloro Mine Site will be monitored in phases during three site rehabilitation time frames:

- Construction Phase
- Operation, maintenance, and monitoring Phase

Monitoring may occur daily, weekly, monthly, or at other specified intervals. Sampling frequency will be gradually reduced as monitoring programs confirm the effectiveness of the rehabilitation measures in reducing the flux of arsenic migrating to the Moira River.

The results of monitoring during construction activities will be documented in a Site Closure Report. During the operation, maintenance, and monitoring phase, annual reports will be prepared that document the results of monitoring activities for that year, discuss past trends in the data, and forecast trends into the future. The overall effectiveness of the cleanup measures will be examined in the annual reports.

Post-Closure Monitoring - The current monitoring program (surface water, groundwater, pumping system, wastewater treatment plant inlet and outlet) will be extended to monitor site conditions and the effectiveness of the site rehabilitation measures. This will include the existing monitoring wells, the surface water sampling stations and the operational sampling stations.

Sampling frequency will be reduced gradually once monitoring confirms the reductions of the loading of arsenic to the Moira River.

Data from the surface water monitoring stations will help determine the effectiveness of the new engineered covers and caps. Site monitoring requirements for the rehabilitated mine workings will continue in accordance with the January, 1994 *Deloro Mine Workings Closure Plan.*

Contingency Measures - The overall cleanup plan is intended to achieve a 90 percent reduction in arsenic loadings to the Moira River to achieve Provincial Water Quality Objectives (PWQOs) at the intersection of the Moira River and Highway # 7. Monitoring will be conducted to assess actual performance.

For More Information on Monitoring Programs

For more detailed information on the various components associated with the monitoring program please refer to the *Deloro Mine Site Cleanup – Integrated Cleanup Plan, Draft Report,* and the four Closure Plan reports.

Appendix C -- Potential Environmental and Socio-Economic Effects

Several environmental and socio-economic factors will likely be affected, to varying degrees, by the cleanup of the site. Such factors include, but are not limited to, the following:

Surface Water Drainage Patterns and Quality -- The draft cleanup plan includes construction of various types of engineered covers. These will cover several thousands of square meters of the site. These structures, combined with the construction of surface water interception ditches in the Industrial Area and the Tailings Area, and the reconstruction of the western bank of the Moira River will likely modify existing surface water drainage patterns. Since these structures will minimize contact between surface water and the wastes, surface water quality will improve significantly as a result of this work.

Groundwater Quality -- Groundwater is currently a significant contributor of contaminants to the Moira River; especially in the Industrial Area. The draft cleanup plan combines several features to minimize the release of contaminants to the environment. Following cleanup work, overall groundwater quality onsite should significantly improve over the long-term.

Air Quality -- Current air quality concerns at the site include potential wind erosion of the calcium arsenate/arsenite pile in the central portion of the Industrial Area. The draft cleanup plan calls for the isolation of the calcium arsenate/arsenite under an engineered cover, which will minimize the wind erosion. Air quality monitoring will be conducted during construction work to ensure the public and onsite workers are not exposed to substances that may pose risks to their health and safety.

Sound Levels -- Construction activities for the site cleanup will require the use of heavy earth moving equipment and trucks. To minimize the impact of potentially elevated sound levels on the local population, working hours will be scheduled to respect municipal by-laws regulating such activities. Sound levels will return to normal following the completion of cleanup work.

Visual Landscapes -- The current state of the local landscape of the Deloro Mine Site is significantly affected by the former mining/industrial use of the site. The overall appearance of the Deloro Mine Site will be significantly improved following the implementation of the cleanup plan.

Land Use -- The perimeter of the Deloro Mine Site is currently fenced to prevent public access to the site. Although the draft cleanup plan calls for the isolation of the onsite wastes and subsequent vegetation of engineered covers, it is unknown whether the current landuse of the Deloro Mine Site will be modified following completion of cleanup work. A heritage plan to preserve and promote the important natural, industrial, social and environmental history of the site is under development.

Vegetation - With the exception of the Main Mine, Industrial and Tailings Areas, the surface of the Deloro Mine Site is currently covered by "natural" vegetation. It is expected that this situation will not be significantly modified as a result of the cleanup. However, the plan includes the integration of grass and hybrid poplar trees as part of the engineered cover design for both

the Tailings and Industrial Areas. This is expected to represent a significant improvement of the vegetative cover of the Deloro Mine Site, in the medium-term, as it will take approximately seven years for the poplars to reach maturity.

Soil - Overall soil quality conditions will improve significantly as a result of the cleanup. Soils currently considered as "contaminated" will be consolidated and isolated under engineered covers in the Industrial and Mine Areas. Areas where contaminated soils will have been excavated will be covered with "clean" soils to promote the growth of vegetation.

Aquatic and Terrestrial Environments - The cleanup plan includes the reconstruction of the western bank of the Moira River in the Industrial Area and the removal of at least a portion of the impacted sediments in Young's Creek. The underlying principle of the plan is to substantially reduce the contaminant loads to the Moira River by isolating the wastes from wind, precipitation and groundwater. Consequently, aquatic environments in the immediate vicinity and downstream of the Deloro Mine Site are expected to benefit substantially from the cleanup. By isolating the wastes and vegetating engineered covers, terrestrial environments of the Deloro Mine Site are expected to improve substantially and to be able to support greater numbers of various species (fauna and flora) over the short to medium term.

Traffic Circulation – Cleanup work is expected to have an impact on local traffic circulation during the active construction period. Measures will be implemented to minimize that impact on public roads. Temporary roads will be constructed on the Deloro Mine Site to allow vehicular circulation on the site itself. The increase in traffic on the roads of the Village of Deloro should be limited to delivery of special materials (if required) and to the daily arrival and departure of site workers for the duration of the remediation.

Residential and Local Business Activity - Like any other important construction project, the cleanup will likely have an impact on the residential activities in the Village of Deloro. As indicated above, higher sound levels and greater transient traffic activity are to be expected during the construction period. Measures will be implemented to reduce these potential impacts to a minimum to respect municipal by-laws dealing with these issues.

The Deloro Mine Site Cleanup Project will require investments of tens of millions of dollars. The project is expected to have a positive impact on local and regional businesses, whether directly or indirectly. Particular segments of the regional economy that will likely benefit from the remediation project are as follows: quarries, earth moving contractors and equipment rental, fuel depots, lodging and food industry, etc. A detailed assessment of the possible interactions between the project activities and the environmental and socio-economic components, and the identification of measures to mitigate potential adverse impacts will be undertaken as part of the environmental assessment for this project.

Appendix D– Characteristics of the Deloro Mine Site

Physiography - The site is located mainly in the Algonquin Highland physiographic region, an area of Precambrian Shield notable for rough relief and shallow, nutrient-poor, droughty soils as well as a climate harsher than in many other parts of southern Ontario. Sandy texture, acidity and low fertility in this area of granite bedrock all contribute to low productivity on limited deep soil. The area is largely non-agricultural because of the rock outcrop and associated shallow soil, rough topography, stones, and swamp.

The physiography of the Deloro Mine Site is characterized by an irregular bedrock surface with numerous outcroppings, primarily toward the north end of the site and along the Moira River. The latter flows through the Deloro Mine Site. The reach of the Moira that intersects the Industrial Area comes into contact with a complex geological and hydrogeological system. In general, the site's ground surface slopes to the south and towards the Moira River.

Geology - The site is located at the contact between Precambrian basement rocks and younger, Palaeozoic sedimentary rocks. Bedrock is exposed primarily at the north end of the site and along the Moira River, which passes through the former mine property. Bedrock outcrops also frequently occur over the area north and northeast of the Industrial Area, where the main mining activities and early milling/refinery operations took place. The bedrock over much of the site is covered by natural overburden, clay fill, building rubble, tailings, slag, or a mixture of all of these. The natural overburden consists primarily of silty clay with minor amounts of silty sand and peat. These native soils are generally found in areas of low topography. In the Industrial Area, fill comprises up to 3 m in the overburden across most of this area, with localized pockets of calcium arsenate and ferric hydroxide (red mud) tailings.

Hydrology - The Deloro site is situated in the central portion of the Moira River Basin. The Moira River drains an area of approximately 2,750 km^2 and flows into the Bay of Quinte on the northern shore of Lake Ontario. The main hydrological feature of the Deloro Mine Site is the Moira River, which flows through the Deloro Mine Site roughly bisecting the property. The river enters the property along the northern boundary and leaves the property at the southwest corner. On the mine site property, the Moira River flows through an area of exposed bedrock and is characterized by a series of rapids, riffle and pool sequences incised over a substrate of bedrock and unconsolidated alluvium.

The surface topography and drainage have been extensively altered over the more than 100 years of mining and refining activity on the site. Surface drainage in the western portion of the site (i.e. west of the Moira River) occurs typically from the west to the east (i.e. towards the Moira River). For a limited fraction of that portion (i.e. the northwestern section), surface drainage is directed to a constructed ditch, referred to as New Westerly Creek, which grades southwards along the western property boundary. Surface drainage in the eastern portion of the site (i.e. east of the Moira River) is controlled by a north-south trending ridge of high ground that bisects the lands in question. Surface waters west of the ridge drain westward to the Moira River, whereas surface waters east of the ridge drain to Young's Creek.

Floodplain mapping predicts that in the event of a 100-year storm the red mud tailings area, one of the inactive sludge lagoons (the former north nickel pond) and the active ferric arsenate sludge lagoon would remain above the flood waters. However, the third inactive sludge pond (the former south nickel pond) and the majority of the sediments within the Young's Creek Area will be submerged.

Hydrogeology - The hydrogeology of the Deloro site is complex as a result of both natural factors and historical industrial development. The following unique factors influence the groundwater regime at the site:

- Location of the Precambrian-Palaeozoic bedrock contact axis
- Changes in the texture, origin and thickness of overburden at the site which, as noted, includes fill, industrial wastes and mine tailings
- Fractured bedrock properties that vary across the site according to bedrock age, type, location, and the degree of human disturbance from blasting and underground mine development
- Rapidly changing topography that varies from elevated bedrock ridges, to low-lying wetlands, to intervening broad, flat areas containing industrial wastes and mine tailings
- Mine shaft pumping and drainage collection systems associated with the onsite Arsenic Treatment Plant

Hydrogeological conditions are better defined in the Industrial Area of the Deloro Mine Site. This reflects the environmental concerns raised by the historical activities conducted in that area. The hydrogeology at the site is also incongruous, with several flow divides that are both natural and constructed. The effect of the groundwater pumping system and mine galleries in conjunction with bedrock outcrops results in an erratic flow system over most of the Deloro Mine Site. However, based on information presented, the overall groundwater flow patterns at the site are from the northwest to southeast on the lands located to the west of the Moira River and from the northeast to the southwest for the lands located east of the Moira River, with the exception of the lands located in the vicinity (i.e. west and north) of Young's Creek, where groundwater likely flows towards Young's Creek.

At the Industrial Area, groundwater flow is locally altered to some extent by constructed features such as the cut-off wall located near the west bank of the Moira River, drainage collection systems and several ponds. There are numerous abandoned buildings and structures that also affect surface and, to a lesser extent, groundwater flow. During the construction of the equalization pond, it was reported that unexpected soil conditions underlying the pond precluded the complete prevention of exfiltration of waters from the pond. Therefore, the equalization pond may be recharging the groundwater and affecting local groundwater flow direction.

Groundwater flows beneath the surface through overburden, bedrock, and/or a combination of both. In the overburden, groundwater flows are concentrated along more permeable material usually lying directly on the bedrock surface. In the bedrock, groundwater flows occur primarily along fractures, bedding planes and similar geological features. Fracture frequency and aperture generally decrease with depth; therefore, groundwater flow through bedrock is expected to be

greater in the shallow bedrock. Bedrock flow patterns are influenced by zones of higher hydraulic conductivity associated with natural faulting and/or folding.

In the overburden, an apparent groundwater divide exists between the old laboratory building and the former primary treatment plant. This divide is probably the result of groundwater being pumped from Pumping Station 5. If the pump does not run sufficiently long, the groundwater levels in the area of the equalization storage basin would likely rise enough for groundwater to flow southeast toward the Moira River.

A groundwater divide exists in the bedrock between the high ground at the former primary treatment plant and the powerhouse to the north. East of this divide, groundwater flows more or less directly to the Moira River. West of this divide, groundwater flows in the bedrock along a longer flow path, eventually discharging to the Moira River at the southeast sector of the Industrial Area.

Flora Communities - The plant communities on the site are fairly typical for an area that is intermediate in disturbance and has a geographical location between northern and southern Ontario. No provincially rare plant communities were found on the site; nor were any provincially or regionally rare, threatened or endangered species of plants found. The highest Floristic Quality Index (FQI) is found in marshes and in mixed and deciduous forest, particularly on the northern part of the site.

Aquatic Ecology - All watercourses within the vicinity of the Deloro Mine Site sampled for fisheries (which were all within the area of potential contamination associated with historic mining activities) can be classified as fish habitat. Field observations indicate that the water bodies abutting the Deloro Mine Site support an assemblage of warm and cool water fish species. Habitat conditions are suitable for a number of fish species. Some species such as largemouth and smallmouth bass are valued as game fish and are present at various locations along the Moira River. Forage fish such as minnows were abundant in marshes downstream of the site. These watercourses support a fishery that is economically important as bait, forage fish and game fish. No threatened or endangered species of fish were found.

Terrestrial Ecology - Wildlife species found are typical of areas of extensive forest in eastern Ontario. There were no provincially or regionally rare, threatened or endangered species of animal life found. None of the wildlife species found at the site have highly specific requirements for habitat, which is likely to become scarce in the area. Many species are already becoming scarce or have been extirpated (locally extinct) in highly urbanized parts of southern Ontario (e.g. wood warblers, black bear) as a result of forest fragmentation, destruction of habitat and urbanization. Therefore, preservation of habitat for these species is unlikely to become a concern at the site in the near future, since a large proportion of the site district is already forested.

Wetlands - Wetlands are mainly confined to Young's Creek, which enters the site at its northeast corner and flows south along the eastern side of the Tailings Area, after which it splits into two wide floodplain channels (the east and west arms). Wetland communities can be found in a narrow band along and in small patches within the Moira River. There are no large wetlands

associated with the Moira River directly on the Deloro Mine Site but there are several immediately south of the site. The Deloro Wetland Complex is a Class 2 provincially significant wetland.

Provincially Significant Areas - An ecological inventory completed at the site indicated that the site is located in an area noted for shallow till and bedrock ridges, till moraines, limestone plain, peat and muck deposits, eskers, and drumlins.

Significant natural features not protected by provincial parks in this area are forested Precambrian bedrock ridges and undeveloped lake shorelines. The Moira River between Chisholm and Latta and near the mouth at Moira Lake contains large provincially significant areas of natural and scientific interest; however, none of the features that contribute to this designation (all related to limestone) are noted within the site.

In 1990, the onsite and offsite (south of Highway # 7) portions of Young's Creek were designated as Provincially Significant Wetlands (PSW). The Deloro Wetland Complex was re-evaluated by Snider's Ecological Services in 2000 as a Class 2 PSW. No provincially significant species of amphibians, reptiles, birds, mammals, or plants were observed in the Deloro Wetland Complex or associated uplands.

Appendix E – Ministry of the Environment Accomplishments

Since assuming control of the Deloro Mine Site as remediator of last resort, the ministry has taken a number of actions that have resulted in an 80 per cent reduction in the amount of arsenic contamination coming off the site. The draft cleanup plan will deal with the remaining 20 per cent of the problem.

Construction of an Arsenic Treatment Plant - When the ministry took control of the site in 1979, the most significant problem was arsenic contamination to the Moira River. Arsenic was leaching into the river at a rate of approximately 52.1 kilograms a day. In 1983 the ministry built an extensive water collection, storage and treatment facility to remove arsenic and other metals from groundwater and surface water runoff.

An 80-metre concrete cut-off dike was built on the west bank of the Moira River to intercept the natural flow of groundwater, to divert it from joining the river, and to treat the contaminated water. Four pumping stations carried groundwater from the site to a storage pond. The water was then treated to remove arsenic and other heavy metals. The results were immediate. Arsenic loadings to the Moira River fell dramatically, lowering the annual average daily arsenic discharge from 52.1 kg/d to less than 10 kg/d. The plant has been working ever since, and is now operated by the Ontario Clean Water Agency (OCWA). This system operates under a Certificate of Approval issued by the province.

Pumping Station 1 is located at the south end of the concrete cut-off dike, east of the former primary refinery building. Pumping Station 2 is at the north end of the concrete cut-off dike. This pump system collects and feeds water to the equalization pond. Pumping Station 3 is located at the south end of the north (or first ferric arsenate) sludge lagoon. This station conveys drainage water from the ferric arsenate sludge lagoon and from collector tiles that intercept the groundwater from the south end of the site extending from the pump to the northwest corner of the castings building. Pumping Station 4 is located at the southeast corner of the calcium arsenate/arsenite storage area.

A fifth pumping station was added south of the equalization pond in 1984 to address suspected groundwater flow toward the wastewater treatment building. Pumping Station 5 is an 8 m deep well, approximately 25 m southeast of the equalization pond that was put in place to intercept groundwater believed to be influencing the water quality south of the plant. The water from Pumping Stations 1 to 5 is routed to the equalization pond.

Pumping Station 6 was established in 1985 to convey Tuttle Shaft seepage to the equalization pond via an aboveground discharge line. The Tuttle Shaft pumping station is only operated during the summer months.

From the equalization pond, collected waters are fed to the treatment plant equipped with a ferric contact reactor, a lime pH adjustment reactor, and a 30-tonne hydrated lime storage silo. From the lime pH adjustment, effluent travels through a 200-mm line to a polymer addition tank to precipitate out arsenic and other contaminants. Finally, the water flows into a large circular collector (i.e. clarifier) in which the precipitates settle out and form a ferric arsenate sludge. An

air compressor runs two pumps that direct the resulting sludge into the ferric arsenate sludge lagoon, located at the south end of the Industrial Area, for dewatering.

The wastewater treatment process is monitored by a pH probe, turbidity meter and suspended solids meter. After treatment, the effluent water is pumped into the make-up water tank or is allowed to outfall into New Westerly Creek, while the sludge from the treatment process is directed to a sludge storage lagoon.

Extensive Ground and Surface Water Monitoring Network - An extensive sampling network was put in place to monitor surface and groundwater quality on and off the site. Collection stations on the Moira River and Young's Creek provide information on surface water, while monitoring wells on the property are used to assess groundwater contamination. Depending on the location of the sampling station, samples are taken hourly, daily, weekly, monthly or quarterly. Samples are analyzed at the on-site lab facilities.

A program including the monitoring of the treatment plant influent and effluent and the groundwater pumping stations was also developed. Annual reports are prepared and submitted by the ministry.

Ongoing monitoring shows that arsenic concentrations in the Moira River have been substantially reduced since the ministry took control of the site. In 1979, the annual average loading of arsenic to the river was 52.1 kg/day. Since the Arsenic Treatment Plant was put in operation in 1983, the arsenic going into the river has been reduced by more than 80 per cent, to an average amount of less than 10 kg/day.

Locating and Sealing Abandoned Mine Shafts - In May 1992, a plan to address mine hazards at the Deloro site was developed with the Ontario Ministry of Northern Development and Mines (MNDM) based on an in-depth review of the mine hazards followed by a survey to locate all mine workings at the site. Investigation activities in the mine area began in July 1992 with the review and analysis of all available and pertinent archival and historical information. An extensive field survey commenced in September 1992 and resulted in the identification and mapping of approximately 110 mining-related features. Ground-penetrating radar was carried out in November and December 1992 to locate suspected underground workings.

In June/July 1993, air-track drilling was carried out to quantify ground-penetrating radar results and to determine the thickness of rock and overburden. Diamond drilling to study the rock mechanics and to determine subsurface geological conditions with respect to existing crown pillars was completed from August to October 1993. Safe access routes into the mine areas on both sides of the river were developed in September and October 1993 and the backfilling of the identified shafts, pits, stopes, and adits was carried out from October 1993 to January 1994. By 1995, all known mine shafts had been located, secured, and either fitted with reinforced concrete shaft caps, or backfilled according to the specifications of MNDM.

Covering Tailings - In 1986/87, approximately 8 ha of ferric hydroxide tailings (red mud), the arsenic contaminated by-product of the smelting process, located on the eastern side of the Moira

River (i.e. the Tailings Area) were covered with crushed limestone. The red mud tailings were covered to a depth of 0.5 metres with approximately 76,000 tonnes of crushed limestone in order to eliminate wind and surface water erosion, elevate the pH of the tailings (as it was thought at the time that the tailings were acid generating) and stabilize the two containment dams.

Simultaneously, measures were undertaken to raise the level of the containment dams and to incorporate filter-graded material. Two engineered catchment basins were constructed downstream to intercept seepage from the dams.

Removing Treatment Plant Sludge - Removal of the dissolved arsenic from the collected groundwater results in the generation of an arsenic-rich ferric arsenate sludge that accumulates in the under-drained lagoon located in the southernmost section of the Industrial Area. As facilities do not currently exist for onsite long-term storage of the sludge, it has been the practice to periodically remove sludge for offsite disposal at a licenced, secure, hazardous waste containment system. For example, approximately 2,000 metric tonnes of sludge were transported to a secure hazardous waste landfill site in the Province of Quebec for treatment and disposal in early 2002.

Demolishing Contaminated Buildings - To address other major sources of arsenic on the site, the ministry demolished a number of contaminated industrial buildings formerly used for collecting and processing arsenic during and following smelting (i.e. pesticides building, arsenic baghouse). The areas where these structures stood were regraded and seeded.

Defining the Extent of the Environmental Problem – Once the mine shafts were sealed and the site was safe for workers, the ministry could proceed with the necessary field work to fill in information gaps, and determine the best options for the final cleanup, containment and management of onsite contaminants. An engineering consulting firm was hired in April 1997 and in-depth field investigations began in June of that year. Problems that had been identified earlier were now studied in greater detail.

As part of the overall cleanup project, the MOE committed to defining the extent of any offsite environmental problems associated with the Deloro Mine Site, including the potential for contamination in the former Village of Deloro and in the Moira River watershed. This lead to two comprehensive studies that are outlined below.

Soil samples taken beyond the boundaries of the mine site in late 1997 showed the presence of arsenic, cobalt, nickel, silver, and other heavy metals. Airborne pollutants released during nearly 100 years of mining and refining are the most likely cause of this contamination. These preliminary findings were reviewed with the local Medical Officer of Health and, after consultation, the MOE concluded there was a need for further investigation.

Deloro Village Environmental Health Risk Study - In 1998, the MOE, in co-operation with the Hastings and Prince Edward Counties Health Unit and the Ministry of Health, launched the Deloro Village Environmental Health Risk Study. This comprehensive, multi-media study examined total exposure to contaminants through air, soil, dust, drinking water, and food to

determine if elevated levels of contaminants were present. It also examined the potential for health risks in the community. The final report, released in July 1999, found the Village is a safe community and there is no significant link between contamination and health risk for the people living in Deloro.

Moira River Study - In December 1998, the MOE also launched a detailed study of the Moira River system to examine the environmental impact of historical contamination from the abandoned mine site on the Moira River. The draft report, released for public consultation in August 2000, and the final report, released in April 2001, found that, despite the presence of historical contamination in the river system, there is no adverse effect on aquatic life and little or no health concern for residents and cottagers downstream of the Deloro site.

Appendix F -- CH2MHILL Technical Investigations

Below is a partial listing of CH2MHILL technical investigations.

#	Title	Date
1	Deloro Mine Rehabilitation Project River Diversion Feasibility Assessment	October 1998
2	Deloro Mine Rehabilitation Project Development of Closure Criteria	October 1998
3	Deloro Mine Rehabilitation Project Potential for Metal Recovery from the Deloro Mine Wastes	October 1998
4	Survey of Moira River Water Use – Update	October 1998
5	Deloro Mine Site Rehabilitation Floodplain Mapping	November 1998
6	Deloro Mine Site Rehabilitation Project Assessment of East Bank Seep – Moira River	November 1998
7	Deloro Mine Site Rehabilitation Ecological Inventory	February 1999
8	Deloro Mine Rehabilitation Project Extent and Character of Radioactive Materials	June 1999
9	Topographic Survey of Waste Isolation Areas	March 2001
10	Geotechnical Investigation of Subsurface Conditions for the Proposed Groundwater Cross-Flow Interceptor	March 2001
11	Moira River Sediment Survey	March 2001
12	Onsite Delineation of Impacted Soil – Summary Report	May 2001
13	Delineation of Young's Creek Sediments – Deloro Mine Site	May 2001
14	Trial Excavation of Frozen Young's Creek Sediments	June 2001
15	Geotechnical Investigation of Subsurface Conditions for the Young's Creek Area	June 2001
16	Deloro Mine Rehabilitation Project Engineering Assessment of the Deloro Dam	June 2001
17	Monitoring Wells Adjacent to Tuttle Shaft	August 2001

18	Deloro Mine Rehabilitation Project General Health and Safety Plan	January 2002
19	Deloro Mine Rehabilitation Project Onsite Data Summary	February 2002
20	Deloro Mine Rehabilitation Project Riverbank Reconstruction Alternatives for the Industrial Area	March 2002
21	Deloro Mine Rehabilitation Project Natural Treatment Technology Feasibility for Tailings Leachate Contaminant Reduction	March 2002
22	Deloro Mine Rehabilitation Project Development of a Sitewide Water and Load Balance	March 2002
23	Deloro Mine Rehabilitation Project Feasibility Study for a Combined Soil Cover and Poplar Tree Cap in the Tailings Area	May 2002
24	Deloro Mine Rehabilitation Project Investitagion of Mine, Tailings and Young's Creek Areas	July 2002
25	Deloro Mine Site Rehabilitation Project Assessment and Reconstruction of Deloro Mine Site Bridge	June 2002
26	Deloro Mine Site Cleanup Delineation of Offsite Sediments and Clay Deposits in Young's Creek and Assessment of Beaver Dams	March 2003
27a	Deloro Mine Site Cleanup Deloro Mine Site Site-Specific Risk Assessment	Under review
27b	Deloro Mine Site Cleanup Offsite Young's Creek Site-Specific Risk Assessment	Under review

Appendix G - Preserving Deloro's Heritage

The Deloro Mine Site has a rich and important history. From its place in the Madoc Gold Rush, to its innovations in creating and producing metals and alloys, Deloro played a key role in the history of mining and industry in Canada. There are many stories to be told about the Deloro Mine Site, its geology, its industry, its innovation and its people. There are also important lessons to be learned about the consequences of reckless exploitation of the environment - a legacy of our uninformed past - and the extensive cleanup that must follow. Telling those stories, and preserving that history has been an important topic of discussion over the past two years.

As the ministry draws closer to completion of cleanup plans, it is important to consider and plan for the future uses of the mine site. Heritage preservation and environmental education are possible uses. In September 2002 the ministry initiated a dialogue on heritage issues with the Public Liaison Committee. The committee was unanimous in its agreement that any recognition and preservation of Deloro's important history would be positive for the community.

Since the ministry's mandate is for environmental cleanup of the site, it cannot take the lead in long-term commemoration efforts. Community leadership is encouraged. However, the ministry did commit to seek out heritage groups and organizations that could help the community, and to bring those people together for a meaningful discussion of possible next steps.

In July 2003 the ministry facilitated that meeting at the Deloro Community Centre. In attendance were representatives from:

- The Ontario Ministry of Culture
- Ontario Historical Society
- Mining Association of Canada
- The Ontario Mining Association
- Hastings County Historical Society
- Marmora Historical Foundation
- Queen's University
- North Hastings Heritage Museum
- Quinte Watershed Clean-up
- Municipality of Marmora and Lake and
- local residents.

While the first priority is to complete the cleanup of the mine site, the ministry is working with the community, heritage organizations, and other provincial ministries to preserve and promote the important natural, industrial, social and environmental history of the Deloro Mine Site.

The ministry engaged the services of the Architectural Conservancy of Ontario's (ACO) Preservation Works! program, to provide a heritage appraisal for the site.

A heritage plan will be developed for the site that will include preservation of several remaining structures on the site, and the possible creation of on-site walking trails and commemorative plaques once the cleanup is complete.

Deloro Mine Site Heritage Initiative Committee

This group of local area residents formed in July 2003 to help preserve and promote Deloro's important history. For more information please contact: Linda Bracken, 147 Rockhaven Road, R.R. 2 Marmora, Ontario, K0K 2M0

Phone/fax: 613-472-3563.
E-mail: l.bracken@sympatico.ca

Appendix H --List of Acronyms

ATP	Arsenic Treatment Plant
C of A	Certificate of Approval
CEAA	Canadian Environmental Assessment Act
CNSC	Canadian Nuclear Safety Commission
DFO	Department of Fisheries and Oceans
EA	Environmental Assessment
EAA	Environmental Assessment Act
EPA	Environmental Protection Act
GIWN	Groundwater Interceptor Well Network
GUCSO	Guideline for Use at Contaminated Sites in Ontario
MNDM	Ministry of Northern Development and Mines
MNR	Ministry of Natural Resources
MOE	Ministry of the Environment
MTC	MOE Technical Committee
OCWA	Ontario Clean Water Agency
OMM	Operation, Maintenance, and Monitoring
PLC	Public Liaison Committee
PWQO	Provincial Water Quality Objectives
SSRA	Site Specific Risk Assessment
TLC	Technical Liaison Committee
USEPA	U.S. Environmental Protection Agency

Appendix I - Project Liaison Committees

Public Liaison Committee

Since 1997, the ministry has been meeting regularly with three project liaison committees to keep them informed and to gather input and comments on reports and recommendations.

This consultation process helps to inform and guide the ministry's remediation plans and work at the site, and downriver. Two of these are external committees -- the Deloro Public Liaison Committee and the Technical Liaison Committee. The third committee is a Ministry of the Environment Technical Committee.

The Public Liaison Committee includes representatives from municipal, environmental and public stakeholder groups in the Moira River area:

- Village of Deloro (residents)
- Quinte Watershed Clean-up
- Quinte Field Naturalists
- Quinte Conservation/Moira River Conservation Authority
- Moira Lake Property Owners' Association
- Stoco Lake (residents)
- Municipality of Marmora and Lake
- Municipality of Centre Hastings
- Mohawks of the Bay of Quinte
- Marmora Historical Foundation
- Deloro Heritage Initiative Committee
- City of Belleville

Technical Liaison Committee

The members of the Technical Liaison Committee represent municipal, provincial and federal agencies with an interest in, or regulatory involvement with, the site:

- Ministry of the Environment
- Ministry of Northern Development & Mines
- Environment Canada
- Department of Fisheries and Oceans
- Ministry of Natural Resources
- Hastings and Prince Edward Counties Health Unit
- Ministry of Labour
- Canadian Coast Guard
- Atomic Energy of Canada Limited. Low Level Radioactive Waste Management Office
- Ministry of Health and Long-Term Care
- Quinte Conservation/Moira River Conservation Authority
- Ontario Clean Water Agency
- Canadian Nuclear Safety Commission

Ministry of the Environment (MOE) Technical Committee

This internal Technical Committee made up of representatives from the ministry's technical branches. Representatives provide advice on technical and regulatory requirements:

- Eastern Region Water Resources Unit
- Eastern Region Abatement Section
- Standards Development Branch
- Water Policy Branch
- Environmental Assessment and Approvals Branch
- Environmental Cleanup Fund
- Legal Services Branch

Deloro Mine Site Cleanup
Industrial Area Rehabilitation Alternatives

Final Report

Prepared for:

ONTARIO MINISTRY OF THE ENVIRONMENT

Prepared by:

CH2MHILL

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Executive Summary

The Deloro Mine/Refinery Site, located in Eastern Ontario, began operation as a gold mine in the 1860s. Over the next 100 years, site activities also included the smelting and refining of a number of other elements including arsenic, silver, and cobalt. Activities associated with the mining, smelting and refining of metals ceased in the 1950s. These historical activities at the site have resulted in significant environmental impacts to the soil, groundwater, surface water and sediment quality both onsite and offsite.

Abandonment of the site by its owner(s) forced the Ontario Ministry of the Environment (MOE) to take control of the property in 1979 and to initiate control measures to limit the environmental impact from the site. Remedial initiatives by the MOE have resulted in reductions of arsenic loadings to the Moira River. Arsenic loading to the Moira River has been reduced by more than 80 percent from an annual average of 52.1 kg/day in 1979 to an annual average of less than 10 kg/day since 1983.

To provide further treatment, and to mitigate any unacceptable impacts on human health and the environment, CH2M HILL Canada Limited (CH2M HILL, formerly CH2M Gore & Storrie Limited [CG&S]) was retained by the MOE to develop and implement a comprehensive rehabilitation program focusing on four individual areas of concern at the Deloro Mine Site. These areas included the Mine Area, the Industrial Area, the Tailings Area, and the Young's Creek Area. The purpose of this report is to identify and evaluate remediation alternatives for the Industrial Area and to select a recommended alternative based on the evaluation.

The Industrial Area is where the smelting and refining of the various ores were carried out. Many of the by-products of these processes still remain in the Industrial Area, and include the following special materials: calcium arsenite, slag, and gold mine tailings. Investigations (CG&S, June 1999) indicate that some of the slag and tailing materials are radioactive. Ferric arsenate sludge from the wastewater treatment plant, composed mostly of ferric arsenate, is also located in a settling lagoon in the southeast portion of the Industrial Area. Other miscellaneous materials, such as building rubble, box inspection holes, and metal storage tanks are also scattered throughout the site.

Groundwater monitoring indicates that the groundwater in the Industrial Area contains elevated levels of arsenic and other metals (e.g. cobalt, copper, mercury, and lead), while surface water monitoring shows that arsenic continues to enter the Moira River from the site. In 1996, for instance, surface water monitoring illustrated that a total arsenic load of approximately 3.2 tonnes/year from the Deloro site entered the Moira River. A water and load balance model developed for the mine site (CH2M HILL, March 2002a) indicated that loading from the west bank of the Moira River is the main area of arsenic loading from the Deloro site, contributing at least 98 percent of the total loading. The analysis estimated that groundwater from the west bank of the Moira River contributes approximately 75 percent of the total site loading for arsenic with 69 percent of it from the Industrial Area. The analysis also estimated that surface water runoff from the west bank of the Moira River contributes approximately 7 percent of the total site loading for arsenic, but may be as high as 37 percent depending on the actual level of arsenic in the runoff.

The evaluation of remediation alternatives was conducted in three stages. The first stage involved the screening of conceptual remediation methods and was designed to identify, early in the evaluation process, the most promising methods for site remediation. In the second stage, comprehensive remediation alternatives were developed by combining the primary remediation methods that satisfied the first screening process with enhancing environmental protection features. Finally, in the third stage, the comprehensive remediation alternatives were compared to detailed evaluation criteria reflecting technical, cost, natural environment, and social considerations. The comprehensive remediation alternative that was judged to be the most effective and efficient means for remediating the Industrial Area was then recommended.

The first step in the generation of remediation alternatives was the development of conceptual remediation methods. The conceptual remediation methods that were identified for the Industrial Area are as follows:

- Do nothing
- Recycling/mineral recovery
- Enhanced groundwater collection
- Stabilization/solidification
- Consolidate and cover
- Cap/cover in place
- Divert groundwater/surface water flow
- Full encapsulation
- Full encapsulation and contaminant leaching

These methods were then screened to eliminate alternatives that would not be effective, would not comply with regulatory requirements, or that could not satisfy the design closure criteria for the site. The methods that were not rejected were classified as either primary remediation methods or enhancing protective features. Primary remediation methods are methods that have the ability to significantly reduce contaminant loading to the environment. Methods that cannot reduce contaminant loads alone can be combined with the primary remediation alternatives to provide additional protection. The combination of primary remediation methods and enhancing protective features forms the comprehensive remediation alternatives.

The comprehensive remediation alternatives were screened a second time using the exclusionary criteria. This step was completed to ensure that the addition of an enhancing protective feature to a primary remediation method did not undermine that method's ability to mitigate risks to human health and the environment. In the case of the Industrial Area, 16 comprehensive remediation alternatives satisfied the exclusionary criteria and constitute the short list of remediation alternatives that was evaluated in detail.

1. Consolidate and cover
    a) Consolidate and cover with ground and surface water flow diversion
    b) Consolidate and cover with ground and surface water flow diversion and selected solidification
    c) Consolidate and cover with ground and surface water flow diversion and selected offsite disposal
    d) Consolidate and cover with ground and surface water flow diversion and enhanced groundwater collection

   e) Consolidate and cover with ground and surface water flow diversion, selected solidification and enhanced groundwater collection
   f) Consolidate and cover with ground and surface water flow diversion, selected offsite disposal and enhanced groundwater collection

2. Cap/cover in place
   – with options a) through f) as above

3. Full encapsulation
   a) Full encapsulation and enhanced groundwater collection

The detailed evaluation resulted in the following comprehensive remediation alternative being recommended for the Industrial Area:

- **Consolidate and cover wastes – Groundwater and Surface Water Flow Diversion.** This comprehensive remediation alternative is the most economical of the ones that were evaluated to be satisfactory at a net present value of $21,404,500. In principle, it has the potential to minimize contaminant migration to the environment and is amenable to the addition of contingency features if required.

The recommended alternative for meeting site closure objectives was based on minimizing the footprint of the leachable wastes in the Industrial Area, protecting these wastes from the elements by encapsulating them under an engineered cover designed to minimize infiltration, and, by diverting groundwater from the wastes and surface water from the engineered cover. Portions of the Industrial Area where less leachable wastes will remain (e.g. the slag and construction debris) will be covered by a simple earth cap.

Operation and maintenance efforts under the recommended alternative will be associated primarily with the ongoing operation of the arsenic groundwater collection and treatment system and the disposal of sludge stored in the ferric arsenate sludge lagoon. Other maintenance efforts will include periodic maintenance of the simple earth cap, engineered cover, surface water interceptor ditch, and reconstructed riverbank to repair any erosion damage and areas of vegetative stress.

Monitoring efforts will be focussed on the monitoring of surface water and groundwater and biomonitoring, if required, at selected locations, to evaluate the effectiveness of the recommended alternative following implementation.

A detailed operations and maintenance plan should be established for the recommended alternative following implementation.

The selection of the recommended remediation alternative is based on the basic principle that the leachable wastes from the Industrial Area should be isolated from media susceptible to promote transport and release of the contaminants to the environment. However, considering the relative complexity of conditions in the Industrial Area (i.e. complex blend of wastes and impacted materials, numerous geological and hydrogeological units, bedrock outcropping, etc.), several unknowns must be resolved prior to the implementation of the recommended, or any other, remediation alternative. These unknowns, referred to as data gaps that should be addressed are identified below:

- Chemical and mineralogical identification of the calcium arsenite stockpile, including arsenic content, firstly since the stockpile's composition may be heterogeneous and secondly, due to its high toxicity.
- Measurements of contaminant bioavailability on the main waste streams present in the Industrial Area. (Results of the bioavailability studies may translate into substantial cost savings for the implementation of the selected remediation alternative if it is demonstrated that the bioavailability of certain wastes is low or negligible.)
- Detailed groundwater flow modelling to evaluate key features of the recommended remediation alternative such as the groundwater flow diversion trench, the potential to create vertically upward hydraulic gradients (under the waste consolidation area), and the impact of the trench on nearby private wells.
- If technically feasible, undertake a cost/benefit analysis of onsite stabilization/ solidification (in-situ and ex-situ) of the calcium arsenite wastes.

The total estimated capital cost for the recommended alternative is $10,434,500 with annual operation and maintenance costs of $838,000. The net present value of the recommended alternative, assuming an effective interest rate of 5 percent and a planning horizon of 20 years, is $21,404,500. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

The recommended alternative will be further developed in a subsequent report entitled Deloro Mine Site Cleanup – Closure Plan for the Industrial Area. The Closure Plan will be the subject of additional public consultation and stakeholder review in addition to providing supporting documentation for regulatory reviews and applications. The comments will be incorporated into the final rehabilitation strategy and implemented in the construction phase of the project.

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Contents

Executive Summary i

1. Introduction 1-1

1.1 Background 1-1
1.2 Purpose of this Report 1-1
1.3 Organization of Report 1-3

2. Background and Problem Definition 2-1

2.1 Deloro Mine Site 2-1
2.2 Industrial Area 2-3
2.3 Previous Investigations in the Industrial Area 2-6
2.3.1 James F. MacLaren Ltd. (1971) 2-6
2.3.2 MOE (1980/81) 2-7
2.3.3 Reid Crowther (1980) 2-7
2.3.4 Trow (1981) and I.E.C. Beak (1984) 2-7
2.3.5 Witteck Development (1986) 2-8
2.3.6 MOE (1986) 2-8
2.3.7 Commonwealth Historic Resources (1988) 2-8
2.3.8 Golder Associates (1988) 2-9
2.3.9 J.L. Richards (1990) 2-9
2.4 Problem Definition 2-10

3. Existing Operations and Impacts 3-1

3.1 Operations 3-1
3.1.1 Groundwater Collection and Treatment 3-1
3.1.2 Groundwater Monitoring 3-5
3.1.3 Surface Water Monitoring 3-8
3.1.4 Soil Investigation 3-9
3.2 Physical Setting 3-9
3.2.1 Climate 3-10
3.2.2 Topography 3-10
3.2.3 Geologic Setting 3-11
3.2.4 Hydrogeology 3-17
3.2.5 Hydrology 3-18
3.3 Natural Environment 3-24
3.3.1 Aquatic Ecology 3-24
3.3.2 Terrestrial Ecology 3-28
3.4 Contaminants in Industrial Area and Contaminant Loading 3-28
3.4.1 Development of a Water Balance and Load Model 3-28
3.4.2 Loading Estimates 3-31
3.4.3 Industrial Area Materials 3-32
3.5 Social Conditions 3-37

4. **Alternatives Evaluation Process** ... **4-1**
4.1 Strategic Direction for Site Cleanup ... 4-1
4.2 Closure Objectives ... 4-1
4.3 Overview of the Process to Generate and Evaluate Alternatives ... 4-2
4.4 Generation of Comprehensive Remediation Alternatives ... 4-2
4.4.1 Screening of Conceptual Remediation Methods ... 4-4
4.4.2 Development of Comprehensive Remediation Alternatives ... 4-5
4.5 Evaluation of Comprehensive Remediation Alternatives ... 4-6
4.5.1 Technical Considerations ... 4-9
4.5.2 Costs ... 4-10
4.5.3 Social Considerations ... 4-10
4.5.4 Natural Environment ... 4-11
4.6 Summary ... 4-11

5. **Development and Evaluation of Alternatives** ... **5-1**
5.1 Remedial and Closure Objectives ... 5-1
5.2 Identification of Conceptual Remediation Methods ... 5-1
5.2.1 Do Nothing ... 5-2
5.2.2 Recycling/Mineral Recovery ... 5-2
5.2.3 Enhanced Groundwater Collection ... 5-2
5.2.4 Stabilization/Solidification ... 5-2
5.2.5 Consolidate and Cover ... 5-3
5.2.6 Cap/Cover in Place ... 5-3
5.2.7 Divert Groundwater/Surface Water Flow ... 5-3
5.2.8 Full Encapsulation ... 5-4
5.2.9 Full Encapsulation and Contaminant Leaching ... 5-4
5.3 Screening of Conceptual Remediation Methods ... 5-4
5.4 Development of Comprehensive Remediation Alternatives ... 5-7
5.5 Screening of Comprehensive Remediation Alternatives ... 5-7
5.5.1 Description of Short-Listed Alternatives ... 5-8
5.5.2 Simple Earth Cap ... 5-13
5.5.3 Engineered Cover ... 5-13
5.5.4 Additional Common Requirements ... 5-33
5.6 Detailed Evaluation of Short-Listed Alternatives ... 5-35
5.6.1 Technical Considerations ... 5-35
5.6.2 Costs ... 5-36
5.6.3 Social Considerations ... 5-39
5.6.4 Natural Environment ... 5-40
5.7 Selection of Recommended Remediation Alternative ... 5-41

6. **Recommended Remediation Alternative** ... **6-1**
6.1 Key Components of the Recommended Alternative ... 6-1
6.1.1 Site Preparation ... 6-1
6.1.2 Construction of Engineered Cover ... 6-1
6.1.3 Construction of Groundwater and Surface Water Interceptor Trench/Ditch System ... 6-1
6.2 Operation and Maintenance Requirements ... 6-2
6.3 Cost Opinion ... 6-2

6.4 Data Gaps 6-3
6.4.1 Identification of the Arsenic Species 6-3
6.4.2 Bioavailability of the Contaminants Present in the Waste Streams 6-3
6.4.3 Detailed Groundwater Modelling 6-4
6.4.4 Long-Term Solidification/Stabilization of the "White Powder" 6-4
6.5 Demolition of Existing Buildings and Infrastructure 6-5
6.5.1 Castings Building 6-5
6.5.2 Cobalt Oxide Plant 6-6
6.5.3 Cobalt Packer House and Plant Dry Building 6-6
6.5.4 Arsenic Packing Shed 6-6
6.5.5 Sludge Lagoon Ruins 6-6
6.5.6 Storage Tanks 6-6
6.5.7 Primary Treatment Building 6-6
6.5.8 Boarding Houses, Hub, and Kitchen 6-7
6.5.9 Powerhouse 6-7
6.5.10 Lab Building 6-7
6.5.11 Old Treatment Plant 6-7

7. References 7-1

Appendixes

A MOE EA Criteria

B Detailed Cost Opinion

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Tables

3.1 Deloro Arsenic Treatment Plant Performance 3-5

3.2 Average Chemical Quality in Groundwater (May 1988 – January 1995)........................3-7

3.3 Flow Velocities in Moira River for a 100-Year Storm Flow 3-24

3.4 Radium Content of Soil Samples..3-34

4.1 Exclusionary Criteria – Screening of Conceptual Remediation Methods 4-4

4.2 Exclusionary Criteria – Screening of Comprehensive Remediation Alternatives..........4-7

4.3 Detailed Evaluation Criteria – Comprehensive Remediation Alternatives 4-8

5.1 Screening of Conceptual Remediation Methods..5-5

5.2 Screening of Comprehensive Remediation Alternatives...5-9

5.3 Evaluation of Short-Listed Comprehensive Remediation Alternatives 5-37

5.4 Evaluation of Short-Listed Comprehensive Remediation Alternatives with Satisfactory Rating..5-43

6.1 Estimated Costs for Implementing Recommended Alternative.......................................6-2

Figures

1-1 Deloro Mine/Refinery Site Showing the Industrial, Mine, Tailings and Young's Creek Areas, Deloro, Ontario 1-2

2-1 Deloro Mine Site Location 2-2

2-2 The Deloro Industrial Area Circa 1961 2-5

3-1 Existing Groundwater Collection and Surface Water Sampling Stations........ 3-3

3-2 Industrial Area Topography Base Plan........ 3-13

3-3 Bedrock Outcrops 3-15

3-4 Shallow Interpreted Water Table Elevation and Groundwater Flow Direction in Overburden........ 3-19

3-5 Interpreted Piezometric Contour Elevation and Groundwater Flow Direction in Shallow Bedrock........ 3-20

3-6 Moira River Watershed Area 3-21

3-7 Flood Risk Map – Moira River........ 3-25

3-8 Flood Risk Map – Young's Creek 3-26

3-9 Approximate Locations of Radiation Fields 3-35

4-1 Screening of Conceptual Remediation Methods – Schematic Diagram........ 4-5

4-2 Development of Comprehensive Remediation Alternatives – Schematic Diagram 4-6

4-3 Evaluation of Comprehensive Remediation Alternatives – Schematic Diagram 4-11

5-1 Schematic Plan View – Consolidate and Cover........ 5-14

5-2 Schematic Cross-Section – Consolidate and Cover........ 5-17

5-3 Schematic Plan– Consolidate and Cover, Groundwater, Surface Water Flow Diversion 5-21

5-4 Schematic Cross-Section – Consolidate and Cover, Groundwater, Surface Water Flow Diversion 5-22

5-5 Schematic Plan and Cross-Section – Consolidate and Cover, Groundwater Flow Diversion, Enhanced Groundwater Collection........ 5-25

5-6 Schematic Plan View – Cap/Cover in Place 5-29

5-7 Schematic Cross-Section – Cap/Cover in Place 5-30

5-8 Conceptual Design for Secure Containment Cell – Schematic Cross-Section........ 5-31

1. Introduction

1.1 Background

Nearly a century of mining and industrial activity has resulted in significant environmental degradation of the Deloro Mine/Refinery site. Tailings and waste zones at the site contain up to 30 percent arsenic. Runoff and seepage from the various waste zones at the site have resulted in arsenic contamination of the Moira River, which flows through the site. Abandonment of this site by its owner(s) forced the Ontario Ministry of the Environment (MOE) to take custody of the property in 1979 and to initiate control measures to limit the environmental impact from the site.

CH2M HILL Canada Limited (CH2M HILL, formerly CH2M Gore & Storrie Limited [CG&S]) was retained by the MOE in April 1997 to develop and implement a comprehensive rehabilitation program for the closure of this former mine site. As part of this comprehensive rehabilitation program, CH2M HILL is developing remediation alternative plans for each of the four areas within the mine site's footprint, as shown in Figure 1-1. The limits of these four areas have been developed based on historical land use and waste disposal practices. The four areas include:

- The Industrial Area, where smelting and refining of the various ores were carried out
- The Tailings Area, where the by-products of the production phase were stored
- The Mine Areas, on both the east and west sides of the Moira River
- The Young's Creek Area, which has been impacted from historical releases from the Tailings Area

Closure plans will be developed for each of these four areas based on the closure objectives identified for the site in the report entitled *Deloro Mine Rehabilitation Project, Development of Closure Criteria, Final Report* (CG&S, October 1998a) and the recommended rehabilitation alternatives developed for each area in the following reports:

- *Deloro Mine Site Cleanup – Industrial Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Tailings Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Mine Area Rehabilitation Alternatives*
- *Deloro Mine Site Cleanup – Young's Creek Area Rehabilitation Alternatives*

1.2 Purpose of this Report

The overall objective of the Deloro Mine Site Cleanup is to successfully rehabilitate the mine site to mitigate, within reason, any unacceptable impacts on human health or the environment. As part of this overall objective, several area-specific objectives have been developed. Achieving these objectives, in conjunction with the other area-specific objectives, will aid in the successful rehabilitation of the Deloro Mine Site.

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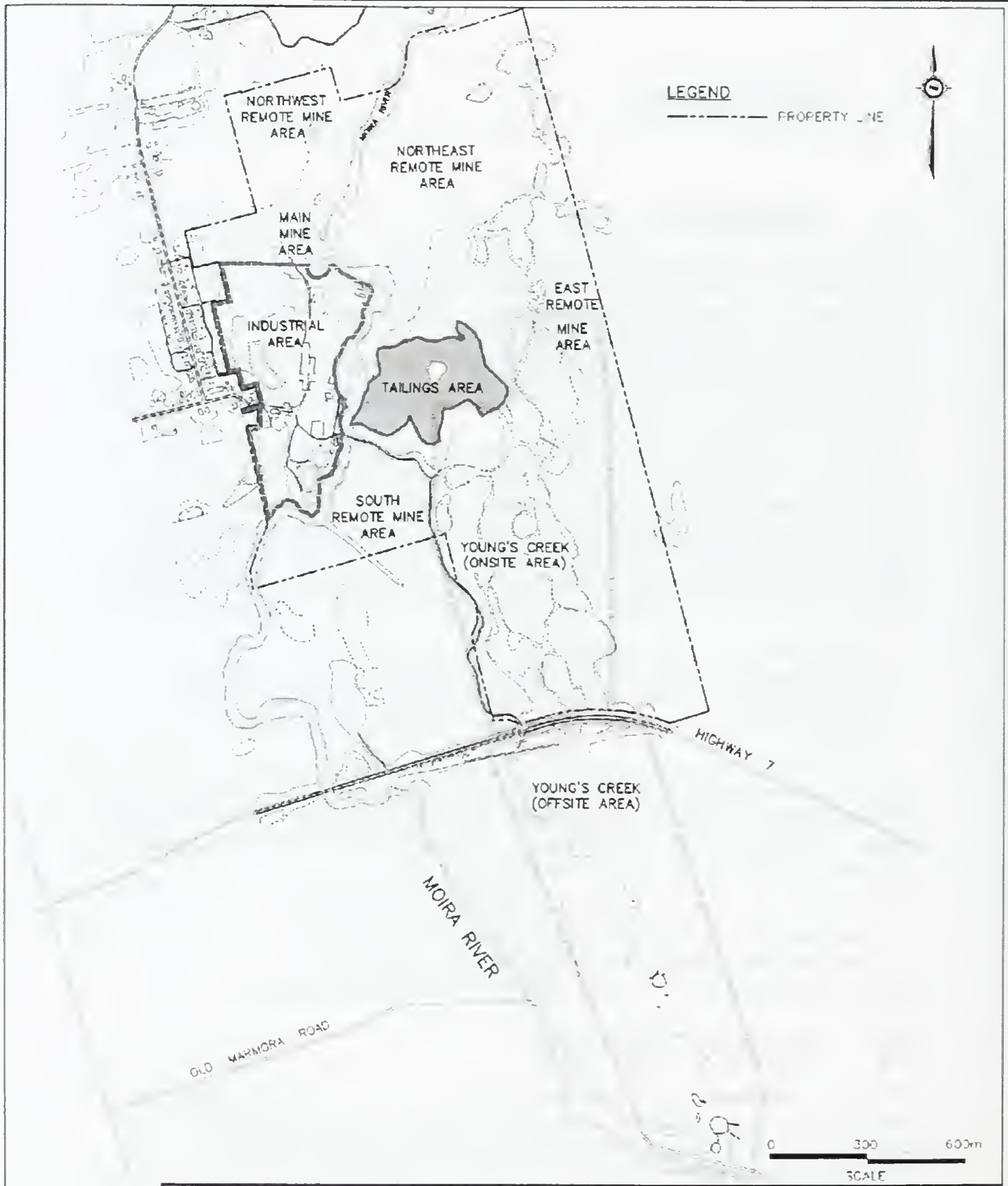

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FIGURE 1-1
DELORO MINE/REFINERY SITE SHOWING THE INDUSTRIAL, MINE, TAILINGS AND YOUNG'S CREEK AREAS
DELORO, ONTARIO

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The alternatives reports summarize the previous investigations and reports that have been commissioned for the subject areas. Several alternatives that have been identified in previous reports are evaluated based on their environmental impacts. The criteria used to evaluate the impacts of alternatives reflect all components of the environment, including natural and social environmental impacts, as well as technical and cost considerations. The evaluation approach also recognizes the need to determine and assess "reasonable" remediation alternatives based on existing site information. The identification of remediation alternatives is not intended to be an exhaustive search for all conceivable or experimental remediation solutions that could be attempted. The recommended alternative for each of the four areas will meet the closure criteria established in the report entitled *Deloro Mine Rehabilitation Project, Development of Closure Criteria, Final Report* (CG&S, October 1998a) and will be further developed in subsequent reports outlining closure plans for each of the areas.

1.3 Organization of Report

This report consists of seven sections, including the introduction. Section 2, Background and Problem Definition, describes the history of the site and a brief summary of the results of previous site investigations and studies within the subject area. The existing physical conditions of the subject area including additional background details and the nature and volume of the contaminated material are described in Section 3. Section 4, Alternatives Evaluation Process, describes the process by which alternatives are generated and the approach to evaluation of the alternatives, as well as the closure objectives that must be met by the rehabilitation alternatives. Additional information pertaining to the detailed evaluation criteria is contained in Appendix A. Section 5, Development and Evaluation of Alternatives, establishes, describes and evaluates rehabilitation methods and alternatives. Section 6 provides the recommended remedial alternatives and cost opinion and identifies any data gaps that should be filled. Details associated with the opinion of cost information are contained in Appendix B. Section 7 lists the references used in the preparation of this report.

2. Background and Problem Definition

This section provides a brief description of the history of the Deloro Mine Site and the Industrial Area and the previous investigations carried out in the Industrial Area. It also clearly defines the problems to be mitigated as part of the recommended remediation alternative. A detailed description of the historical mining activities that have taken place at the Deloro Mine Site since the early 1860s is provided in the report entitled *An Historical Analysis of the Deloro Site* (Commonwealth Historic Resource Management Limited, January 1988).

2.1 Deloro Mine Site

The Deloro site is located in Eastern Ontario along the banks of the Moira River on the eastern boundary of the Village of Deloro (see Figure 2-1, Deloro Mine Site Location). The former refinery/smelter site (Industrial Area) is approximately 25 ha in area and is located adjacent to the west bank of the Moira River. The Tailings Area is located east of the Industrial Area between the East Side of the Moira River and the West Side of Young's Creek. The entire property, which includes the Industrial Area, Tailings Area, Mine Area, and the onsite portion of Young's Creek, is approximately 202 ha in area (CH2M HILL, February 2002).

Access to the mine site is via Deloro Road, which is accessed from Highway 7, approximately 4 km east of Marmora. The principal population centres in the area are the Village of Deloro (pop. 180), and the Villages of Marmora (pop. 1,700) and Madoc (pop. 1,400), located approximately 5 km southwest and 10 km east of the mine site, respectively.

The Deloro site began operation as a gold mine in the 1860s and evolved over the next century to mine and refine gold, as well as smelting and refining of a number of other elements including arsenic, silver and cobalt. It was the first plant in the world to produce cobalt commercially and was also a leading producer of stellite, a cobalt-chromium-tungsten alloy. Concentrates from uranium extraction were imported to the site and further processed to extract cobalt. Arsenic-based pesticides were produced from the by-products of smelting operations and continued as a main activity at the site until the market collapsed in the late 1950s.

A century of handling hazardous materials and chemicals has resulted in significant environmental degradation of the Deloro Mine Site. Large quantities of refining slag, mine tailings, calcium arsenate, and arsenical pesticides remained at the site. Fuels, chemicals, and raw materials, such as sulphuric acid, coke, lime, soda ash, caustic soda, liquid chlorine, salt, scrap iron, sodium chlorate, and fuel oil were handled at the site. Radioactive slag and tailings were produced as a result of the re-refining of by-products from uranium refining.

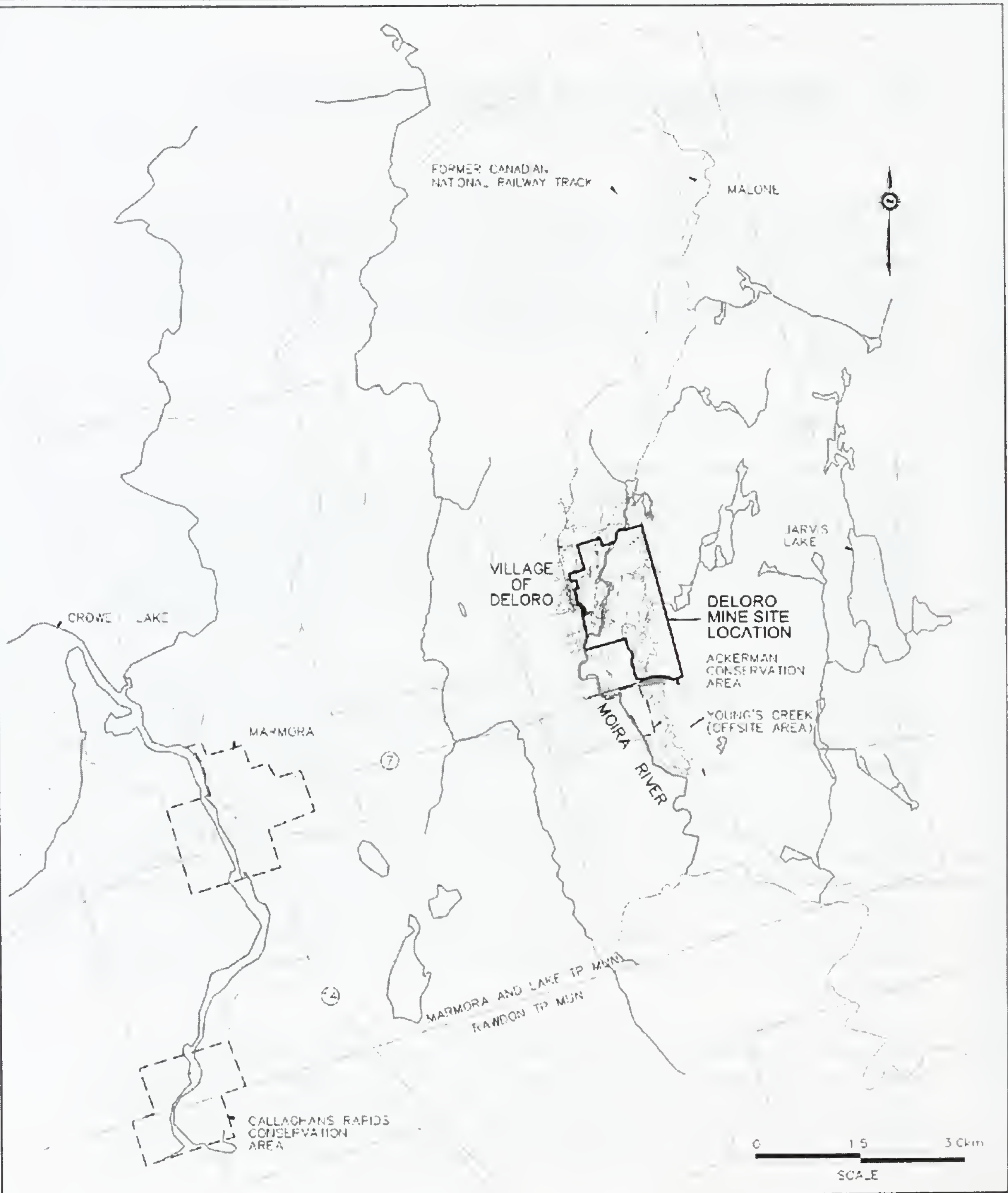

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FIGURE 2-1
DELORO MINE SITE LOCATION

PROJECT No. 119548

The Ontario government stepped in to take control of the site in 1979 due to failure of the owner to control environmental releases. The MOE has been in care and control of the site since that time. Several rehabilitation actions have been implemented at the site to date that have significantly reduced releases from the site. In 1979, the annual average loading of arsenic to the Moira River was 52.1 kg/day. Since the arsenic treatment plant was put into operation in 1983, the arsenic loading to the river has been reduced by more than 80 percent, to an annual average of less than 10 kg/day. However, further work is required to reduce releases to acceptable levels and to secure the site for the long term. CH2M HILL was retained in April 1997 to provide consulting engineering and project management services for the Deloro Mine Site Cleanup.

2.2 Industrial Area

All gold mining operations at the Deloro Mine Site ceased circa 1902 because of the relatively low grade and tonnage of the deposits and metallurgical difficulties in refining caused by the high levels of arsenic in the ore. Silver ores, discovered in Cobalt, Ontario, contained high levels of arsenic, which made silver recovery difficult. At the time, the Canadian Goldfields plant at Deloro was the only facility in Ontario able to treat high arsenic ores.

Between 1907 and 1961, the Deloro site was used for metallurgical and refining processes related to the production of cobalt oxides and metal, and the extraction of silver, nickel, and arsenic. Until about 1930, the ores were obtained from Cobalt and Gowganda, Ontario, after which time concentrates containing cobalt were also received from other sources including the Eldorado Nuclear Refinery in Port Hope, Ontario. These concentrates were radioactive to a varying degree, as were the resulting waste slag materials, which were placed around the site at various locations. Cobalt-copper ores were also received from the Belgian Congo and Rhodesia during the Second World War and used in the production of stellite metal (a cobalt-chromium-tungsten alloy). The processes involved the use of cyanide, sulphuric acid, caustic soda, soda ash, and chlorine.

The main waste products included:

- Ferric hydroxide tailings (red mud), which were initially placed in the wetlands to the northwest portion of the present day Industrial Area and subsequently pumped to an enclosure on the east side of the Moira River, where it covers an area of approximately 8 hectares (i.e. the Tailings Area)
- Barren solutions, which were discharged to two settling ponds at the south end of the Industrial Area for precipitation of metals prior to discharge to the river
- Slag, which was piled mainly to the north, west, and southwest of the castings building but that has also been crushed and placed elsewhere on the site (including the western bank of the Moira River in the central portion of the mine site)

- Wastes from metallurgical and chemical research laboratories thought to have generally been dumped adjacent to these facilities with small volumes of toxic materials placed in a "poison pond" located to the west of the main refinery slab and south of the calcium arsenite[1] stockpiles
- Arsenic compounds

Refining of arsenic compounds from the gold and silver/cobalt/nickel ores was carried out at the site from the early 1900s to 1958. A large volume of arsenic trioxide powder was recovered from the refining processes in the arsenic baghouse and packing houses and stockpiled/stored in open piles or barrels and, after 1920, the powder was purified into various arsenate compounds and sold commercially as an agricultural insecticide. The arsenic recovery area was located adjacent to the western shoreline of the Moira River in the east central part of the site; the pesticide processing buildings were located in the northern portion of the site, on higher ground, between the powerhouse and the Tuttle Shaft. When the market for arsenic-based pesticides declined in the late 1950s, the arsenic trioxide was converted to calcium arsenite, reportedly through treatment with lime, and stockpiled in the north central part of the site (i.e. the Industrial Area). Arsenic compounds and pesticides were also disposed of elsewhere on the site, including the hillside adjacent to an old backwater of the Moira River to the north of the Gatling Shaft. Figure 2-2 shows a plan view of the Industrial Area as it appeared in the early 1960s.

The northwest portion of the plant site was originally a low-lying, poorly drained wetland area. Drainage of this area was undertaken in the early 1950s by the construction of Old Westerly Creek, which flowed southeast past the primary treatment and castings buildings and discharged directly to the Moira River in a natural depression opposite the north nickel pond. This creek was suspected of carrying surface drainage from the plant and calcium arsenite areas. A livestock kill downstream of the site in 1958 has been attributed to either arsenic from site operations, washing of calcium arsenite into the river, or the accidental creation of highly soluble sodium arsenite (Golder, 1988). In 1959, Old Westerly Creek was diverted into the south nickel pond, with lime and magnesium sulphate added to reduce arsenic loading to the river in the pond overflow. In 1962, the creek was diverted to the New Westerly Creek (NWC) alignment along the western property line with the intent of intercepting and diverting surface water running onto the site away from the arsenic sources in the main plant area; the creek entered a clay tile pipe through the central portion of its route and discharged into a wetland prior to reaching the Moira River south of the plant site. However, significant quantities of arsenic-bearing waters from the working area infiltrated into NWC and the Moira River. The "poison pond" was capped with clay and underdrains were installed in the calcium arsenite area; the collected water was pumped to a relatively ineffective treatment plant and then into the south nickel pond (Golder, 1988).

[1] The actual form of arsenic by-product is uncertain and is reported to be either calcium arsenite or calcium arsenate in various sources. Throughout this report, calcium arsenite will be used to designate the arsenic containing residuals from the production of arsenic trioxide

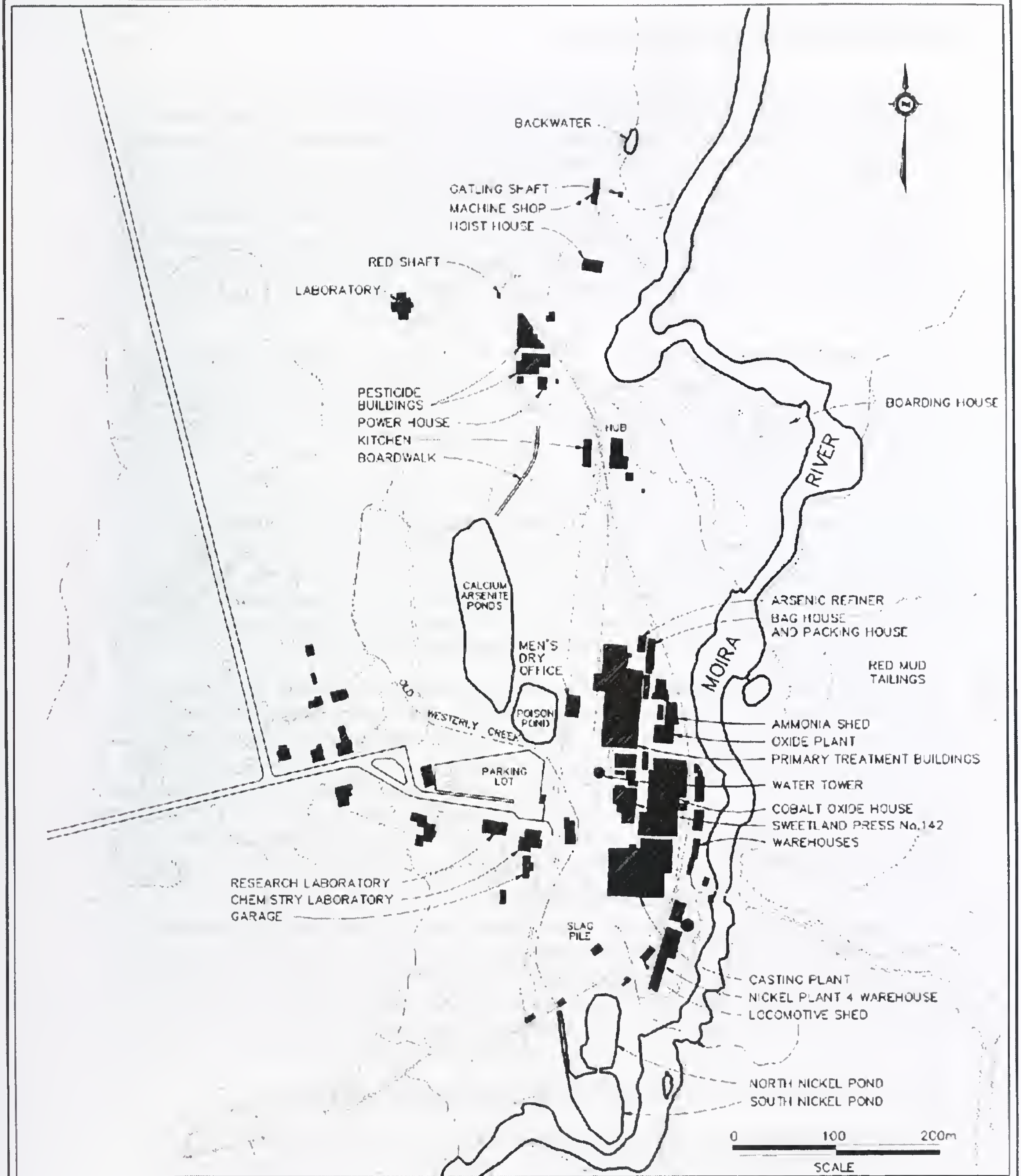

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FIGURE 2-2
THE DELORO INDUSTRIAL AREA
CIRCA 1961

PROJECT No. 119548

Source: Commonwealth Historic Resource Management, 1988

In the early 1960s, the Ontario government began monitoring arsenic levels in the Moira River. Investigations in 1971 by James F. MacLaren Ltd. indicated that significant arsenic loading to the Moira River was taking place from groundwater and surface water sources in the area of the arsenic baghouse and packing shed. Clay dykes were constructed adjacent to the river in this area and a collection tile/forcemain system was installed; the waters were pumped to an equalization pond (1973) in the southeast part of the site and then were treated prior to entering the former nickel ponds. Excess sludge build-up in the ponds and leakage from the ponds presented problems. In 1974, the settling ponds were dredged and the sludge was disposed of in a localized area on top of the red mud tailings on the east side of the Moira River (i.e. the Tailings Area).

In 1978, the MOE ordered the site owner, Erickson Construction Company Limited, to take steps to control the discharge of arsenic to the river. The company failed to comply with the order issued under the Environmental Protection Act (EPA) and declared a lack of operating funds. In 1979, the MOE assumed control of the abandoned site and the arsenic treatment system as remediator of last resort.

In 1982, the MOE renovated the former research laboratory building on the site and constructed a new arsenic treatment plant. The plant began operations in 1983 and collects, stores and treats arsenic-contaminated groundwater. Groundwater, including water diverted by an 80-m-long barrier wall grouted into bedrock and located along the western bank of the Moira River, is pumped from six pumping stations to an equalization storage basin. The arsenic concentrations, which range from 50 mg/L to 1,500 mg/L, are equalized in the storage basin for more efficient treatment at the treatment plant.

An iron/lime treatment process, which uses ferric chloride, lime, and a polyelectrolyte, treats the collected groundwater. Sludge from the process is dried in an under-drained lagoon and the treated effluent, with 99.5 to 99.9 percent of the arsenic removed, is returned to the Moira River. Loadings and arsenic concentrations in the river have been substantially reduced by the current collection and treatment operations. The annual average daily loading of arsenic to the Moira River in 1979 was 52.1 kg/day compared with 3.7 kg/day in 1994 (OCWA, 1997b). Similarly, the average annual arsenic concentrations in the Moira River decreased from 0.33 mg/L in 1979 to 0.03 mg/L in 1994 (OCWA, 1997b), as measured at the Highway 7/Moira River monitoring station.

An extensive program is in place to monitor surface water and groundwater quality at the Deloro site. The program includes the monitoring of the treatment plant influent and effluent and the groundwater pumping stations. Two monitoring networks on the Moira River and Young's Creek provide information on surface water quality and a series of monitoring wells on the mine site property assess groundwater quality.

2.3 Previous Investigations in the Industrial Area

Investigations and studies that have been carried out at the site are briefly described in the following paragraphs.

2.3.1 James F. MacLaren Ltd. (1971)

In 1971, James F. MacLaren Ltd. studied arsenic contamination at the site, which included some subsurface investigation, the monitoring of groundwater levels and the measurement

of arsenic concentrations in the vicinity of the north end of the smelter and in the arsenic handling areas to the east (MacLaren, 1971). This study indicated that groundwater and surface water runoff containing levels of arsenic with concentrations greater than 1,500 ppm were flowing under steep gradients in both surface water and groundwater directly to the river in this area. The report suggests that arsenic contamination existed between the primary treatment building slab and the calcium arsenite piles (which may be related to the calcium arsenite ponds that used to exist in the area). This study resulted in the installation of two clay cut-off dykes and a collection tile/forcemain system in this area that fed into an existing treatment plant, followed by construction of an equalization pond to coordinate discharge with treatment capability and river flow.

2.3.2 MOE (1980/81)

After taking custody of the site in 1979, the MOE conducted detailed sampling of the Moira River at Deloro and prepared a report (MOE, 1980/81a). Using the results of measured arsenic concentrations in the Moira River at various sampling points along its length, the percent of arsenic loading from various portions of the mine/refinery site was estimated. The results indicated that the majority of arsenic loading (57 percent) occurs opposite the main plant site/arsenic handling area between the Deloro falls and the mine site bridge; about 21 percent between the mine site bridge and the discharge depression associated with Old Westerly Creek from leakage from the north nickel pond and drainage from the slag pile; about 14 percent from the Tuttle Shaft and further upstream; and 8 percent from discharges from the south nickel pond, NWC, and waste materials upgradient of the wetland area between the south nickel pond and NWC.

In 1980, the Deloro Dam was used by the MOE to dewater the Moira River for a period of 23 days to observe and analyze seepage from the river banks opposite the Deloro site and to determine where interceptor/collector systems should be constructed (MOE, 1980/81b). The major seepage area identified was opposite the former arsenic baghouse. Downstream areas opposite the plant dry buildings and cobalt sheds were other identified seepage areas.

2.3.3 Reid Crowther (1980)

In 1980, *A Remedial Clean-Up Program for the Deloro Site* was developed for the MOE by Reid, Crowther & Partners Ltd. (Reid Crowther, 1980). Based on site inspections and existing information, but in the absence of site geological and hydrogeological studies, short-term and long-term plans for remediation were provided. The short-term recommendations implemented were the cut-off wall (i.e. barrier wall), groundwater collector/forcemain system, arsenic treatment plant, and the equalization pond and sludge lagoons presently in use at the site. The long-term measure suggested was a secure encapsulation of the site with the goal of abandoning the need for operation of the treatment plant.

2.3.4 Trow (1981) and I.E.C. Beak (1984)

In order to design and implement the Reid, Crowther & Partners Ltd. short-term program, a geotechnical investigation was carried out by Trow Ltd. in 1981 in the area proposed for construction of the equalization pond to the northwest and along the cut-off wall alignment (Trow, 1981a&b). This investigation involved sampling of 21 boreholes. Design recommendations were provided for a 1-m-thick clay-lined equalization pond and a concrete cut-off wall grouted into the underlying bedrock. It is understood that, during construction, the

clayey silt soil expected below the entire equalization pond was discontinuous (especially in the northern portion) and considerable dewatering effort was required to control groundwater when water-bearing silty sands were exposed. As well, a bedrock outcrop was encountered in the east central pond sideslope. Construction supervision was carried out by Trow.

Construction of the current groundwater collection/treatment works was carried out in 1982/83. The new ferric arsenate sludge lagoon was constructed in 1984 to the southeast of the castings building by berming above the existing ground; excavation was not attempted because of potential problems with water-bearing sands and the Old Westerly Creek alignment, which underlies the sludge lagoon. The lagoon was not designed or constructed to prevent exfiltration.

The problem of handling the volumes of ferric arsenate sludge produced from the treatment plant was realized, and a study of methods to dewater the sludge was undertaken by I.E.C. Beak Consultants Ltd. in 1984 (I.E.C. Beak, 1984). This study included an experimental freeze-drying bed on a relatively small scale.

2.3.5 Witteck Development (1986)

A study into the potential for utilization of mineral processing wastes and by-products at Deloro was carried out by Witteck Development Inc. in 1985 (Witteck, 1986). The program for this study involved extensive sampling/profiling of the major waste areas on the site and then chemical/mineralogical characterization. This characterization resulted in the estimate of 8,000 tonnes of slag, 90,000 tonnes of red mud tailings, and 6,200 tonnes of calcium arsenite. Potential uses/markets for these materials were provided.

2.3.6 MOE (1986)

In May 1986, a presentation entitled the *Deloro Update* was prepared by MOE personnel involved with the Deloro site rehabilitation (MOE, 1986). This document reviewed the advantages and disadvantages of various options for handling/disposing of waste materials on the property. The recommendations were as follows:

- The 6,200 tonnes of calcium arsenite in stockpiles, which contribute to groundwater and surface water contamination, should be made secure by appropriate capping and collection systems.
- The ferric arsenate sludge, which is fairly stable at present, requires that drying beds be established to reduce the volume and a permanent disposal area established onsite. Certificates of Approval will be required for disposal of the sludge onsite, as well as for the calcium arsenite.
- Total site rehabilitation is desirable both in terms of contaminants and site safety hazards.

2.3.7 Commonwealth Historic Resources (1988)

In 1988, Commonwealth Historic Resource Management Ltd. prepared a historical analysis of the Deloro site for J.L. Richards & Associates Ltd., prime consultant for the MOE (Commonwealth, 1988). The research was collected from various sources such as the Trent

University archives, the Marmora Herald, and the Ontario Bureau of Mines and Department of Mines Annual Reports. The report focuses on the history of activities at the site.

2.3.8 Golder Associates (1988)

In 1988, Golder Associates produced a hydrogeological/geotechnical investigation report for J.L. Richards & Associates Ltd. (Golder, 1988). The investigation included a review of previous studies, an overburden and bedrock drilling and monitoring well installation program, geophysical surveys, and a detailed reconnaissance to identify and inventory waste materials. Chemical analyses of groundwater, surface water, and soils were conducted along with a search for earth borrow materials, which would be suitable for aspects of site remediation works.

The majority of the groundwater flow was found to be east to southeast from the Village of Deloro towards the Moira River. The monitoring and sampling showed the onsite groundwater in both overburden and bedrock to be contaminated with arsenic as well as containing varying degrees of mercury, lead, cyanide, and other metals.

2.3.9 J.L. Richards (1990)

In 1990, J.L. Richards & Associates Ltd. produced a report summarizing the historical study, health and safety considerations, hydrogeological studies, and various remediation alternatives (Richards, 1990). Study findings showed that the current treatment plant has succeeded in removing approximately 13,360 kg of arsenic per annum with a removal efficiency of 99.7 percent between 1984 and 1987 inclusive.

The report stated that virtually all of the soils on the Deloro site are considered contaminated. Some have been classified as hazardous materials under the testing procedures in the former Ontario Regulation 309 (now O.Reg. 347).

The results of the hydrogeological survey suggested that up to 80 to 90 percent of the arsenic loading to the Moira River is from direct surface runoff of near surface flow from large meteorological events and the spring melts. The report also suggests that if the wastes were to be contained and secured with a low permeability cover, the arsenic loading to the river would be reduced by 50 percent or more.

The report recommended the preservation of the existing groundwater collection and treatment system and the current groundwater and surface water monitoring program. A relocation of the fence to coincide with the property line was suggested. The report also recommended that a filter press and an addition be added to the arsenic treatment plant. A new onsite containment cell could be constructed to receive the ferric arsenate sludge. The existing sludge could be dewatered and placed in the new secured cell or consolidated with the calcium arsenite. A secure top cover for the calcium arsenite with a perimeter sub-drain connected to the groundwater recovery system was the suggested control measure. The report recommended all of the non-hazardous wastes be collected and buried as part of the site grading program and that the remaining buildings be demolished and buried. A low permeability cap could be constructed to isolate the wastes from the surrounding environment.

2.4 Problem Definition

The Industrial Area is where the smelting and refining of the various ores were carried out. Many of the by-products of these processes still remain in the Industrial Area, and include the following special materials: calcium arsenite, slag, and gold mine tailings. Investigations (CG&S, June 1999) indicate that some of the slag and tailing materials are radioactive. Ferric arsenate sludge from the wastewater treatment plant, composed mostly of ferric arsenate, is also located in a settling lagoon in the southeast portion of the Industrial Area. Other miscellaneous materials, such as building rubble, box inspection holes, and metal storage tanks are also scattered throughout the site.

Groundwater monitoring indicates that the groundwater in the Industrial Area contains elevated levels of arsenic and other metals (e.g. cobalt, copper, mercury, and lead), while surface water monitoring shows that arsenic continues to enter the Moira River from the site. In 1996, for instance, surface water monitoring illustrated that a total arsenic load of approximately 3.2 tonnes/year from the Deloro site entered the Moira River. A water and load balance model developed for the mine site (CH2M HILL, March 2002a) indicated that loading from the west bank of the Moira River is the main area of arsenic loading from the Deloro site, contributing at least 98 percent of the total loading. The analysis estimated that groundwater from the west bank of the Moira River contributes approximately 75 percent of the total site loading for arsenic with 69 percent of it from the Industrial Area. The analysis also estimated that surface water runoff from the west bank of the Moira River contributes approximately 7 percent of the total site loading for arsenic, but may be as high as 37 percent depending on the actual level of arsenic in the runoff.

3. Existing Operations and Impacts

This section describes the existing rehabilitation efforts of the MOE, and the current impacts on the Moira River from the Industrial Area. It also presents a review of the materials existing on the site that must be accounted for as well as the problem and the impacts that must be mitigated as part of any rehabilitation program.

3.1 Operations

3.1.1 Groundwater Collection and Treatment

A groundwater collection system exists onsite. It is designed to capture arsenic impacted groundwater before it reaches the Moira River. It initially consisted of four pumping stations (Richards, 1990), an 80-m-long cut-off wall grouted into bedrock located at the western bank of the Moira River, a 9,084-m^3 equalization pond (i.e. equalization storage basin), and an arsenic treatment plant. A fifth pumping station (Richards, 1990) was added south of the equalization storage basin in 1984 to capture suspected groundwater flow towards the treatment building. During low-flow periods in the summer months, groundwater seepage from the former Tuttle Shaft in the Main Mine Area was found to have a measurable effect on the water quality of the Moira River. A sixth pumping station was installed in the Tuttle Shaft in 1985 (Richards, 1990) to convey Tuttle Shaft seepage to the equalization storage basin via an above ground discharge line. The Tuttle Shaft pumping station is only operated during the summer months. Figure 3-1 shows the layout of the existing groundwater collection system.

Upon entering the treatment plant from the equalization storage basin, the feed water passes through a flow meter and into a 2,135-L ferric chloride reactor. Within the reactor, the waters are mixed with ferric chloride for a nominal retention time of 5 minutes. The ferric chloride is pumped into the contact tank from one of two 23,000-L solution tanks. This step allows the arsenic to react with the iron.

From the ferric chloride reactor, the waters flow into a 4,012-L lime reactor with a nominal retention time of 10 minutes. The waters are mixed with the lime slurry that is pumped into the tank from a 2,273-L mix tank. The slurry tank is fed from a 30-tonne hydrated lime storage silo and mixed with water from a 4,546-L makeup water storage tank. The makeup water can be either municipal water or plant effluent. The slurry is volumetrically fed to the lime reactor by a VFD (variable frequency drive) pump which is electronically adjusted by the pH probe in the lime reactor. The lime raises the pH which causes a ferric arsenate precipitate to form.

From the lime reactor, the waters travel through a 200-mm line to a polymer reactor tank. They are mixed with a polymer solution to assist the formation of a ferric arsenate floc; the nominal retention time is 5 minutes. The polymer bags are placed into a dustless bag breaker and fed through a helix screw feeder into a wet box where the polymer dissolves in municipal water. The wet box discharges into the mix tank where the polymer is mixed and aged until it is needed.

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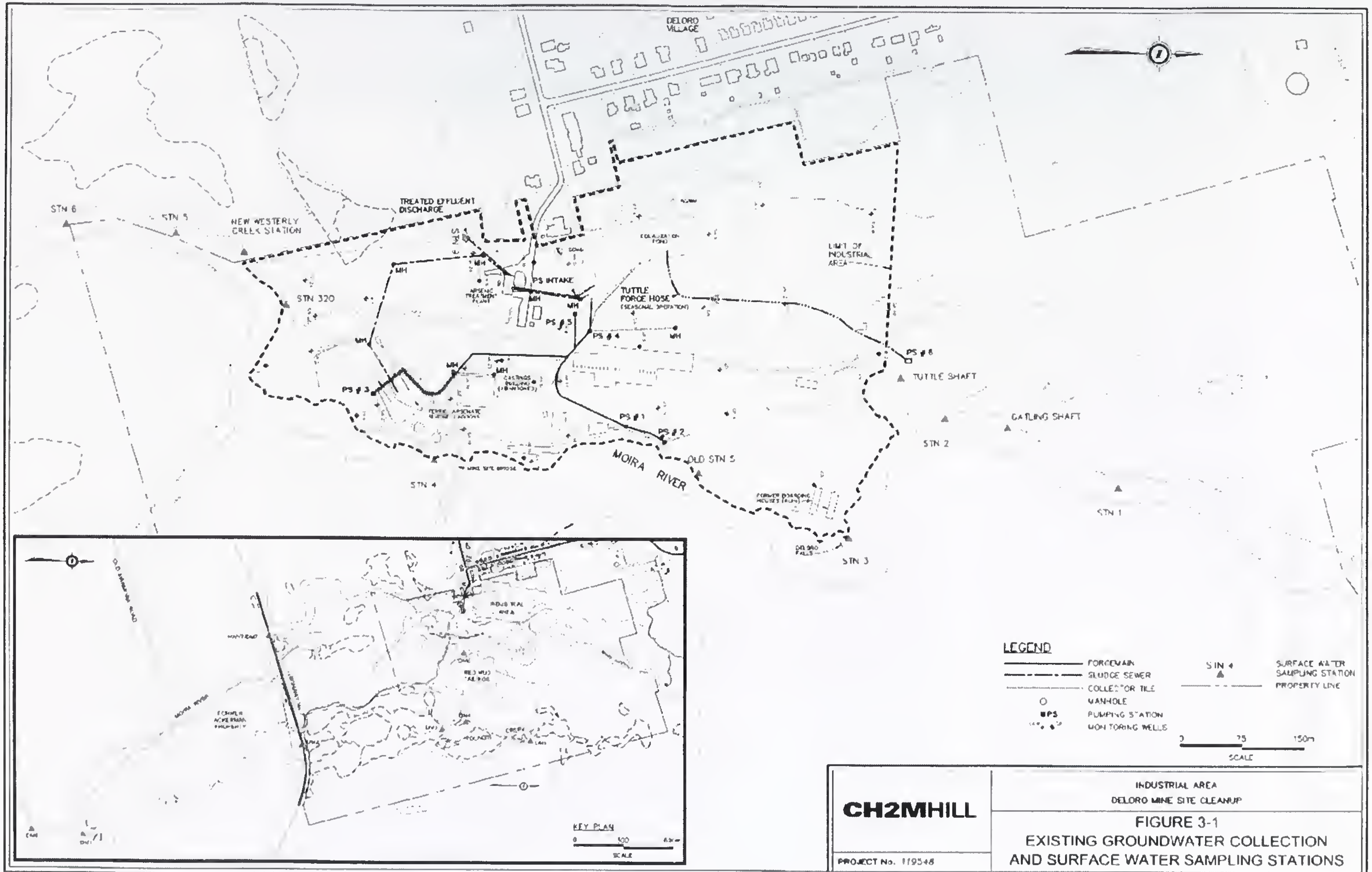

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INDUSTRIAL AREA

DELORO MINE SITE CLEANUP

FIGURE 3-1
EXISTING GROUNDWATER COLLECTION AND SURFACE WATER SAMPLING STATIONS

PROJECT No. 119548

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Finally, the waters flow into a large circular sludge clarifier 4.6 metres in diameter. The ferric arsenate flocs settle out and form a ferric arsenate sludge. One air compressor runs two pumps that feed the process sludge (7.5 percent solids content) to the ferric arsenate sludge lagoon at the south end of the Industrial Area. The sludge storage lagoon, which is based on a natural freeze/thaw dewatering design, is under-drained with a collection system. Excess water from the dewatering process drains by gravity to Pumping Station #3 and is returned to the equalization storage basin for treatment.

The effluent discharge is monitored by a pH probe, turbidity meter, and suspended solids meter. After treatment, the effluent water is pumped into the makeup tank or is allowed to outfall into NWC. The sludge from the treatment process is pumped to the sludge storage lagoon through a 100-mm sludge sewer. The sludge sewer can be accessed at three points by inspection holes located approximately 60 m apart.

Since assuming control of the site in 1979, the MOE has implemented various remediation strategies to reduce the arsenic loading to the Moira River, including the operation of the arsenic treatment plant since 1983. These measures have had a significant positive impact on river water quality, lowering the annual average daily arsenic loading from 52.1 kg/day to consistently less than 10 kg/day. Table 3.1 summarizes the arsenic treatment plant's performance.

TABLE 3.1
DELORO ARSENIC TREATMENT PLANT PERFORMANCE

Year	Water Treated (m^3)	Influent As (mg/L)	Effluent As (mg/L)	Treatment Efficiency (%)	Arsenic Removed (kg)
1984	82,295	189	0.361	99.8	17,787
1985	127,705	133	0.202	99.8	14,294
1986	168,422	89	0.223	99.7	13,561
1987	153,610	87.775	0.153	99.8	13,273
1988	164,341	99.334	0.127	99.9	15,729
1989	104,567	120.741	0.177	99.9	11,733
1990	99,842	110.071	0.194	99.8	10,913
1991	*	144.499	0.227	99.8	*
1992	87,139	161.714	0.199	99.9	12,734
1993	88,717	138.141	0.223	99.8	11,478
1994	169,868	105.313	0.187	99.8	16,380
1995	78,528	112.173	0.151	99.9	8,618
1996	86,525	147.696	0.164	99.9	12,738

* Problem with Flow Meter
Source: OCWA, 1997a

3.1.2 Groundwater Monitoring

Groundwater within the Industrial Area has been sampled on a regular basis since 1988. These samples are submitted for analysis and the results are tabulated (OCWA, 1997c).

The groundwater monitoring system has been separated into two functional groups:

- Operation samples
- Monitoring well samples

The operation samples are drawn from the six pumping stations and the two groundwater inspection holes (i.e. the north groundwater man hole [NGWM] and the south groundwater man hole [SGWM]). All samples have been tested for arsenic and heavy metals, including aluminum, cobalt, copper, lead, mercury, molybdenum, nickel, and zinc.

Forty-seven original monitoring wells were installed by Golder Associates in 1988 (Golder, 1988). Thirty-nine wells remain from which groundwater samples can be collected and analyzed. The eight wells that do not yield water samples are either dry or have been compromised.

Monitoring wells GA 6 and GR 1 were selected to represent "background" during the Golder Associates study based on the absence of the major contaminants, such as arsenic, cobalt, mercury, cyanide, etc. Well GA 6 is located in the northwest portion of the site, approximately mid-span to the equalization storage basin and is representative of the overburden "background." Well GR 1 is located in the northeast section of the site south of the Tuttle Shaft and is representative of non-mineralized bedrock "background." This well was drilled directly into the granite outcrop. The location of wells GA 6 and GR 1 as well as the remainder of the "GA" and GR" series of monitoring wells are shown on Figure 3-1.

Although the natural groundwater seems to be relatively free of most metal species, the background wells show evidence of elevated levels of arsenic. The other wells (excluding GA 6 and GR 1) display varying levels of contamination. With the exception of arsenic, cobalt, and mercury, the individual average concentrations over time have been relatively low. The overall average concentrations as compared to the existing or interim Provincial Surface Water Quality Objectives (PWQO) appear elevated for arsenic, cobalt, and copper. Both arsenic and mercury are known to occur in the natural bedrock in the vicinity of the site.

Arsenic concentrations in the overburden groundwater have ranged from non-detect in the background well to 2,190 mg/L in the well located immediately downgradient of the central portion of the Industrial Area. With the exception of well GA 24, the arsenic concentration has exceeded the existing PWQO of 0.100 mg/L in every listed well at one point in the monitoring history.

In the bedrock, the arsenic concentration ranges from 0.05 mg/L in the deep rock at the extreme south end of the Industrial Area to 1,400 mg/L in the shallow rock east of the central portion of the Industrial Area. A high spike of 2,100 mg/L was measured in October 1993 in the well immediately north (i.e. upgradient) of the concrete cut-off wall (i.e. GR 3).

In addition to the elevated concentrations of arsenic, the groundwater in the Industrial Area also contains elevated levels of other metal contaminants. Many of the wells exhibit elevated levels of cobalt exceeding 100 µg/L and elevated levels of copper exceeding 23 µg/L (OCWA, 1997c).

Table 3.2 summarizes the average results of groundwater monitoring between 1988 and 1995.

TABLE 3.2
AVERAGE CHEMICAL QUALITY IN GROUNDWATER (MAY 1988 – JANUARY 1995)

Well	pH	Cond. (ms/cm)	Al (mg/L)	As (mg/L)	Co (mg/L)	Cu (mg/L)	Hg (µg/L)	Mo (mg/L)	Ni (mg/L)	Pb (mg/L)	Zn (mg/L)
GA 1-1	7.313	0 711	0 317	13 031	0 079	0 040	0 039	0 025	0 042	0 033	0 016
GA 1-2	7 23	0 79	3 456	11	1 805	1.701	4 901	0 029	0 845	0.068	0 315
GA 2-1	7 35	0 94	0 241	887 60	0 035	0 016	0 264	0 111	0 048	0 028	0 017
GA 2-2	8 22	1 31	2 057	1042 4	0 211	0 031	31 617	0 202	0 149	0 167	0 035
GA 3	6.37	1.21	0 315	526 35	0 214	0 007	0 058	0 215	0 019	0 036	0 013
GA 4	7 05	2 52	0 333	12 133	1.779	0 031	0 063	0 026	0 760	0 023	0
GA 5	6 48	1 55	0 471	2 576	5 322	0 060	0 079	0 010	2 050	0 020	0 024
GA 6[1]	7.31	0 67	0 256	0 178	0 028	0 008	0 022	0 008	0 019	0 019	0 027
GA 7	7.35	0 75	0 267	0 892	0 035	0 006	0 036	0 011	0 009	0 017	0 004
GA 8	7.37	0 59	0 597	11 239	0 029	0 013	0 208	0 013	0 031	0 017	0 03
GA 9	6.98	1 41	0 251	13 714	0 021	0 008	0 139	0 017	0 011	0 032	0 007
GA 12-1	9 07	0 79	1 425	79 432	0 627	0 088	0 136	0 162	0 039	0 020	0 008
GA 12-2	11.92	3 00	1 212	15 942	0 178	0 208	0.263	0 389	0 050	0 040	0 012
GA 14	7 26	1 41	0 574	29 386	10 900	0 061	1.107	4 893	2 815	0 024	0 354
GA 15	7 27	1.14	4 444	29 727	7 146	0.098	1 671	0 045	1 042	0 018	0 1
GA 16	7 46	0 67	0 772	2 579	0 868	0 074	6 799	0 103	0 285	0 031	0 035
GA 18	7 22	0 61	0 862	27 289	0.420	0 022	0 145	0 041	0.127	0 018	0 208
GA 19	7 48	1 03	4 357	34 594	9 426	0.499	53 359	0 234	3 554	0 244	0 28
GA 20	7.38	0 89	1 004	11 715	0 170	0 010	1 829	0 055	0 033	0 011	0 006
GA 21	8 01	1.00	5 554	26 585	0 529	0 469	18.175	0 076	1 217	0 073	0 098
GA 22	7 43	0.97	0 187	13 650	0 049	0 004	2 008	0.134	0 029	0 041	0 003
GA 23	7 19	1 07	9 365	11 189	0 155	0 068	1 439	0 019	0 078	0 068	0 095
GA 24	7 38	0 97	0 095	0 022	0 031	0 008	0 000	0 031	0 015	0 034	0
GR 1-1[2]	7.65	1 16	0 297	1 579	0 010	0 011	0 063	0 039	0 009	0 011	0 009
GR 1-2	7 70	1 62	1 351	108 62	0 011	0 015	0 234	0 049	0 012	0 020	0 011
GR 2-1	7 25	1 65	1 531	63.860	0 051	0 015	0 262	0.039	0 035	0 039	0 015
GR 3-1	6 57	2 87	0 305	271 95	0 511	0 013	3 388	0 138	0 340	0 058	0 019
GR 3-2	6 90	3 33	0 351	1301 3	0 201	0 013	57 530	0 152	0 082	0 077	0 013
GR 3-3	7 01	3.35	0 305	465 15	0 220	0 021	18 00	0 094	0 061	0 145	0 013
GR 4-1	7 31	1 26	0 341	17 008	0.054	0 011	0 068	0.033	0.049	0 019	0 013
GR 4-2	6 92	1 75	0 41	15 288	0 283	0 010	1 902	0 056	0 141	0 039	0 009
GR 5-1	7 79	1 82	0 376	77 083	0 257	0 015	0 117	0 170	0 022	0 030	0 012
GR 5-2	7 65	1 02	0 362	167 11	0 119	0 012	0 738	0 119	0 016	0 013	0 004
GR 5-3	8.41	0.68	0 366	56 647	0 149	0.015	0 660	0 112	0 053	0 038	0
GR 8-1	7 35	1 27	0 365	0 271	0 029	0 016	0 025	0 037	0 017	0 037	0 048
GR 8-2	7 18	0 98	1 618	1 789	0 017	0 011	0 589	0 037	0 023	0 023	0 071
GR 9-1	7 51	0 76	0 237	15.423	0 293	0 010	0 051	0 036	0 068	0 026	0 004
GR 9-2	7 24	0 78	0 272	24.082	0 355	0 010	0 047	0 059	0 080	0 026	0 003
GR 9-3	7 09	0 84	6 658	15 401	0 733	0 050	0 502	0 054	0 221	0 054	0 074
GR 10-1	7 26	0 99	0 285	10 215	3.129	0 007	0 024	0 041	0 432	0 005	0.009
GR 10-2	7 24	1 25	0 265	19 381	0 267	0 010	0 049	0 024	0 051	0 012	0 011
GR 11-1	7 81	1 74	0 305	0 338	0 019	0 018	0 043	0 048	0 020	0 014	0 01
GR 11-2	7 75	0 52	2 134	1 116	0 16	0 011	1 79	0 042	0 012	0 010	0 009
GR 12	7 47	0 64	0 334	0 679	0 006	0 005	0 035	0 023	0 012	0 022	0 006
Average	7 48	1 28	1 293	123 57	1 066	0 087	4 783	0 187	0 341	0 041	0 047
MOE Table A Potable Groundwater Criteria (1997 Guideline for the Cleanup of Contaminated Sites in Ontario)			–	0 025	0 1	0 023	0 12	7 3	0 1	0 01	1 1
PWQO[3]			(0 075)	(0 005)	0 0009	(0.001)	0 2	0 04	0 025	(0 001)	(0 02)

Source OCWA, 1997c.
Notes. [1] Background monitoring well (overburden)
[2] Background monitoring well (non-mineralized bedrock)
[3] PWQO = Provincial Water Quality Objectives for protection of aquatic life ( ) = Interim PWQO

3.1.3 Surface Water Monitoring

Sampling stations have been established to monitor the effect the Deloro site has on the surface water quality of the Moira River and Young's Creek. The sampling stations have been divided into two separate sample runs: the Moira River sample run and the Young's Creek sample run. The following is a description of the sample sites.

Moira River Sample Run

- Stn 1 – Station 1 is located at the river and is upstream of the Deloro site.
- Gatling – Samples are collected from the Gatling Shaft runoff to the river.
- Stn 2 – Station 2 is located at the river between the Gatling and Tuttle locations.
- Tuttle – Samples are collected from the Tuttle Shaft runoff to the river.
- Stn 3 – Station 3 is located downstream of the Tuttle Shaft and just north of the Deloro falls east of the boarding house ruins.
- Stn 4 – Station 4 is located immediately upstream of the weir south of the mine site bridge.
- DM 6 – Samples are collected from the runoff west of the west tailings dam which eventually makes its way to the river.
- Stn 320 – Samples are collected from the runoff through the old equalization pond and dump.
- NWC – Samples are collected from the runoff at NWC to the river.
- Stn 5 – Station 5 is located approximately 100 m downstream of the NWC station.
- Stn 6 – Station 6 is located approximately 200 m downstream of Station 5.
- Hwy7/DM 7 – Highway 7 and the Moira River represents the downstream point for the Moira River sample run; and the upstream Moira River point for assessing the Young's Creek contribution.

Young's Creek Sample Run

- DM 5 – Samples are collected from Young's Creek at the head of the beaver dam (Upstream point).
- DM 3 – Samples are collected from the beaver dam, south of DM 4 and east of the east tailings dam.
- DM 4 – Samples are collected from the runoff east of the east tailings dam to Young's Creek.
- DM 2 – Samples are collected from Young's Creek at Highway 7.
- Hwy7/DM 7 – Samples are collected from the upstream Moira River point for assessing the Young's Creek contribution.
- DM 1 - Samples are collected from Young's Creek at the Moira River (before Young's Creek enters the river).
- DM 8[2] - Samples are collected from the Moira River downstream of Young's Creek.

[2] Sampling began in 1993

Figure 3-1 shows the location of the operation and surface water sampling stations.

Routine surface water sampling at the Deloro site dates back to 1980 and has been tabulated (OCWA, 1997b). The samples are currently analyzed for arsenic and heavy metals including aluminum, nickel, lead, copper, cobalt, mercury, molybdenum, and zinc. Testing for cyanide was conducted in the years preceding 1991 but has since been discontinued, as it has not been detected at significant levels at the site.

Based on annual average calculations, the arsenic concentration has increased by as much as 58 times the background or upstream value as the Moira River crosses the Industrial Area. The yearly averages for arsenic at several of the sampling stations exceeded the annual average site objective of 0.05 mg/L, and the interim PWQO of 0.005 mg/L (MOE, 1994). The interim PWQO was exceeded based on monthly averages, especially in the late summer months.

When the surface water arsenic values are observed from upstream of the Industrial Area through to the Highway 7/Moira River sampling point, the arsenic values (mg/L) rise steadily, as illustrated by the following station results for the month of July 1996:

Month	Stn 1	Stn 2	Stn 3	Stn 4	Stn 5	Stn 6	Stn 8
July	0.002	0.004	0.038	0.042	0.053	0.056	0.056

A ten-fold increase in the arsenic concentration occurs between Station 2 and Station 3. The Golder Associates report (Golder, 1988) suggests that the major influence to the river concentration occurs in the vicinity of the Tuttle Shaft.

The results in the Golder Associates report (Golder, 1988) also showed mercury increasing as the Moira River crosses the site. Results for mercury have been non-detect or comparable to upstream background levels in most recent years. Results have been below the PWQO of 0.2 μg/L (MOE, 1994). The detection limit for mercury is 0.1 μg/L.

3.1.4 Soil Investigation

Soil samples were collected by Golder Associates from various locations and test pits excavated throughout the Industrial Area. The samples were digested in hydrofluoric acid (HF). This test procedure was suggested by the laboratory in order to establish realistic results of metal species that may be adsorbed very strongly to the soil particles (Golder, 1988). This method gives an accurate representation of the contaminant species but not the leaching potential of those species in the natural environment.

Golder Associates (Golder, 1988) collected and analyzed 27 samples of soil, 17 of which contained arsenic levels exceeding 10,000 ppm. Nine samples contained arsenic with concentrations exceeding 1,000 ppm. Elevated levels of other heavy metal species, particularly cobalt, nickel, copper, and mercury, were detected in samples collected throughout the site.

3.2 Physical Setting

This section describes the physical characteristics of the Deloro Mine Site and the Industrial Area.

3.2.1 Climate

The Deloro area and the surrounding region receive an average yearly precipitation of 889-mm (Environment Canada, 1990). Maximum precipitation usually occurs in the month of September with approximately 80 to 100 mm of rain. The spring growing season of April, May, and June accounts for about one quarter of the yearly precipitation. The months of September, October, and November account for about one quarter of all precipitation either as rain or snow.

The spring to fall average mean temperature is 16.9°C. The winter mean temperature is -7.4°C. The daily minimum average temperature for January and February is -13.4°C and the daily maximum highs average 25.3°C for the June to August period. The minimum and maximum average temperatures result in a maximum annual range of approximately 38.7°C. The record high was recorded in the summer of 1988, when temperatures exceeded 40.6°C over a seven-day period. The record low for the area is -40°C. Winds in November to March prevail from the west and in the spring and summer months winds prevail from the southwest.

3.2.2 Topography

The Industrial Area is located near the geologic contact between the Precambrian (about 1,400-million-year-old) shield to the east and the relatively flat-lying Palaeozoic (about 450-million-year-old) limestones, which underlie the extreme west of the site and most of the village.

The surface of the Precambrian bedrock is very irregular and reflects weathering processes during early Palaeozoic times prior to the deposition of the limestone strata that now covers much of the area west of the property. The irregular bedrock surface often protrudes through the overburden forming prominent bedrock knobs over much of the site. In general, the ground surface at the Deloro site slopes to the south and to the east toward the Moira River. The overburden is generally thin (less than 3 m) but is up to 9 m thick in some areas. Elevations over the site range from approximately 205 metres above sea level (masl) along the north boundary of the Industrial Area to approximately 185 masl along the banks of the Moira River and in low-lying areas in the south of the property.

The surface topography and drainage have been extensively altered over the more than 100 years of mining, refining and manufacturing activities on the site. Surface drainage is currently divided by a ridge of high ground that trends north-south through the middle of the property. To the west of this ridge, some of the runoff is collected by a creek known as New Westerly Creek. This creek is a constructed ditch, which drains into a wetland on the southwest part of the property and then eventually drains into the Moira River. The original creek, Old Westerly Creek, flowed diagonally across the site and discharged to the Moira River at a point coincident with the current active ferric arsenate sludge lagoon. The remainder of the runoff flows easterly and southerly to the Moira River.

Four constructed ponds/lagoons are located on the site. Three ponds/lagoons are located at the south end of the Industrial Area; the other pond/lagoon is an equalization storage basin in the west central part of the site that holds contaminated water awaiting treatment. The two southernmost ponds/lagoons (former nickel ponds) contain water but are not interconnected; the south nickel pond contains surface water with elevated arsenic levels (Golder, 1988) and drains into the Moira River when pond levels are high. The remaining

pond/lagoon is the active ferric arsenate sludge lagoon that has an underdrain system leading to the equalization storage basin for treatment.

Figure 3-2 shows the principal topographic features of the Deloro site/Industrial Area.

3.2.3 Geologic Setting

The general geologic setting involves the mine site being is located at the contact between Precambrian basement rocks and overlying Palaeozoic sedimentary rocks. Bedrock is exposed primarily at the north end of the site and along the Moira River, which passes through the MOE-controlled property. Young's Creek, to the east of the site, is established in a topographic depression flanked by low bedrock scarps and outcrops. The bedrock over much of the site is covered by natural overburden, clay fill, building rubble, tailings, slag, or a mixture of all of these. The natural overburden consists primarily of silty clay with minor amounts of silty sand and peat. These native soils are generally found in areas of low topography.

Bedrock Geology

Precambrian metasedimentary and metavolcanic rock forms the bedrock under most of the site except for the western edge of the property, which is underlain by Palaeozoic limestones and shale, and the eastern portion of the property, which is underlain by the Deloro Pluton—a felsic intrusive ranging from granitic to syenitic in composition (Chapman and Putnam, 1984). The syenitic phase of the intrusion is more prevalent on the southern half of the Deloro Pluton. A few skarn lenses occur within 300 m northwest and southwest of the major mine shafts. Granitic phases include syenite, granite, and diorite. The granite is typically pink, massive, medium-grained, and well jointed. The bedrock generally has a northwesterly strike and dips steeply. Joint orientations in the rock trend northeasterly and northwesterly. Frequent weathered fracture planes at 60 to 80 degrees from horizontal were noted in the granite below the cut-off wall along the Moira River.

Areas of exposed bedrock are shown on Figure 3-3. Bedrock outcrops frequently occur over the area north and northeast of the main plant site, where the main mining activities and early milling/refinery operations took place. A bedrock high exists to the north of the primary treatment building and passes southward beneath this structure. A bedrock ridge rises sharply along the site access road, continues beneath the MOE arsenic treatment plant, and extends a significant distance to the south. The bedrock slopes off eastwards beneath the slag pile, westward towards NWC, and southward towards the old equalization pond. In borehole GA 25, to the west of the castings building, and borehole GR 6, north of the castings buildings, respectively, the bedrock is overlain by approximately 2.8 m and 4.6 m, respectively, of slag. Bedrock outcrops discontinuously along the Moira River from the mine site bridge southward to the NWC discharge. Bedrock has been exposed by site excavation work along the west side of the north nickel pond and along the southwest and southeast sides of the south nickel pond. These pond locations are the result of localized depressions in the bedrock and placement of fill materials.

Beneath the main slag pile to the northwest of the castings building is an apparent decline in the bedrock surface trending northeast to southwest from an elevation of approximately 191 masl in the northwest to an elevation of approximately 187 masl in the area of the castings and cobalt oxide buildings. This eastwardly declining bedrock surface continues northward through the arsenic packing shed/baghouse area.

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31/OCT/2003

LEGEND

PROPERTY LINE
FENCE
BENCH MARK
HYDRO POLE

0 50 100m
SCALE

NOTE
SURVEY COMPLETED BY FARNCOMB KIRKPATRICK AND STIRLING SURVEYING LTD ON AUG. 31, 1999 WITH REFERENCE TO BENCH MARK 401 EL. 197.378 masl
CONTOUR INTERVAL IS 0.5m

CH2MHILL

INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-2
INDUSTRIAL AREA TOPOGRAPHY BASE PLAN

PROJECT No. 113546

44248FE1

3-13

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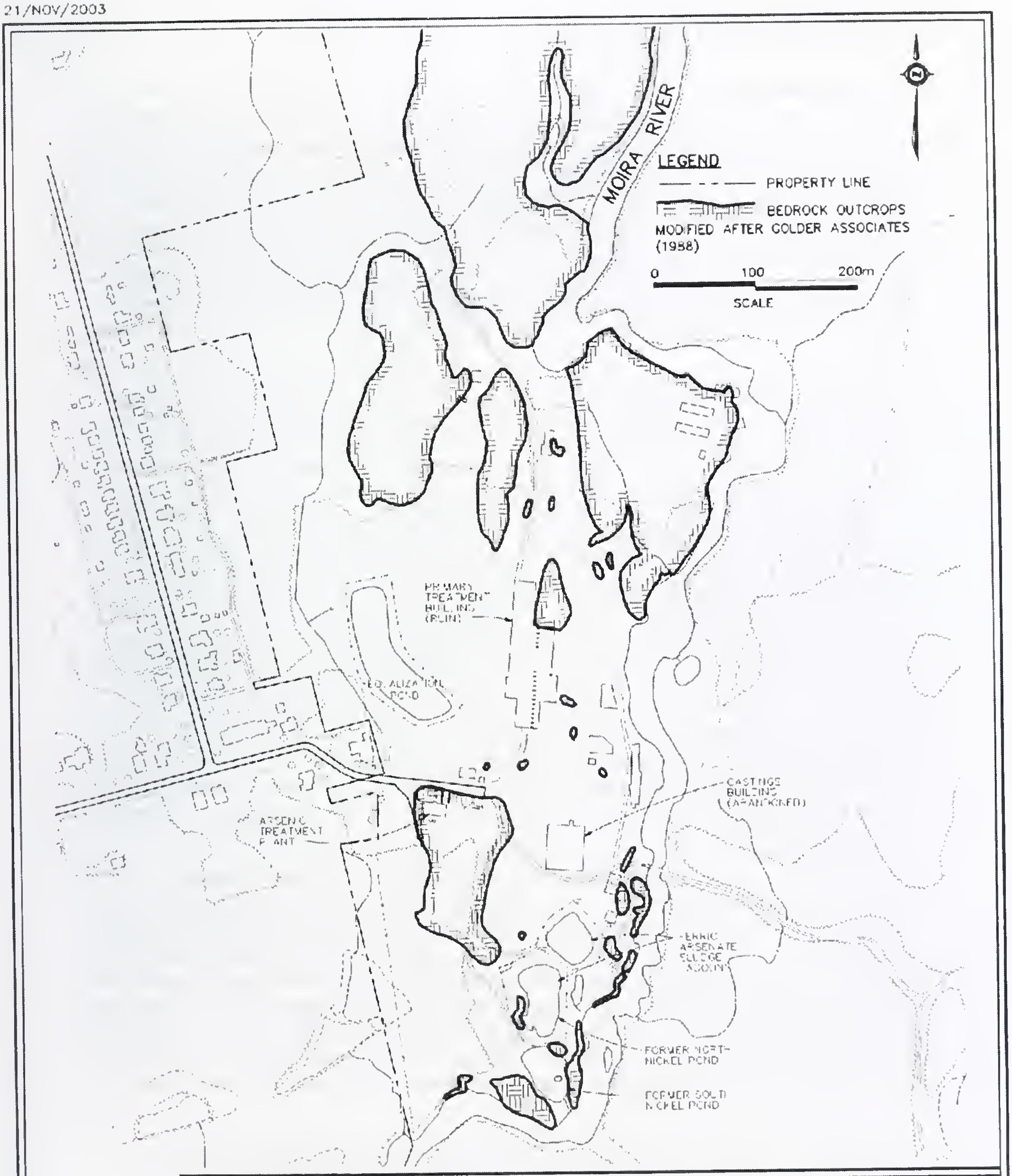

CH2MHILL

INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 3-3
BEDROCK OUTCROPS

PROJECT No. 119548

Overburden Geology

The deepest overburden is encountered in the vicinity of the equalization storage basin within an area bounded by the primary treatment building slab on the east and NWC on the west. Bedrock in this area is typically present between 6 and 9 m below ground surface. Bedrock within this zone forms a "bowl" bounded by bedrock outcrops or subcrops north of the calcium arsenite stockpile, beneath the former primary treatment building and the arsenic treatment plant. This part of the site was originally a poorly drained wetland, which was filled with various waste materials. The original ground surface across most of this area was determined by Golder Associates (Golder, 1988) by the presence of organic soils at an elevation of approximately 193.5 masl. Current elevations within the area range from 194 to 197 masl.

Fill comprises up to 3 m consisting mainly of red brown silty clay and brown sandy silt, with sand and gravel inclusions, slag, cobbles, and organic material. Localized pockets of a white, powdery material (chemical characterization of this material indicates it may be calcium arsenite) and ferric hydroxide (red mud) tailings are also present in localized areas.

The calcium arsenite stockpile covers an area of approximately 160 m by 70 m in the central part of the area. The calcium arsenite was placed in lifts with the north portion of the pile being approximately 0.75 m higher than the south. Both portions of the stockpile are currently covered by a thin layer of slag to prevent dusting. Golder Associates (Golder, 1988) indicated that the thickness of the north portion of the stockpile pile is approximately 2.4 m and the south pile is approximately 1 m thick, corresponding to a base elevation of approximately 194.5 masl. Considering available borehole data, about 1 m of unknown fill material may exist between the base of the stockpile and the underlying organic soils. The advancement of boreholes during the 1988 investigation of the site indicated additional calcium arsenite buried beneath fill material to the east/northeast of the main calcium arsenite stockpile. Boreholes GA 2 and GA 12 encountered about 1 m of grey-white material suspected to be calcium arsenite below 2.1 to 2.9 m of earth fill. The presence of this material indicates that the calcium arsenite stockpile extends northward into the depression between the bedrock outcrops.

Organic soils (0.2 to 1.6 m) consisting of dark brown peat, very soft cream-coloured calcareous marl, and organic silty clay are located beneath the fill. This peat, marl, and clay represents all or a portion of the thickness of organic cover in this originally poorly drained area of the site. The organic soils are generally underlain by a layer of silty clay to clayey silt soils, which range in thickness at the borehole locations from 1.5 to 5.6 m, but are typically 2 to 3.5 m thick. The clay ranges in colour from grey to grey-brown depending on the degree of weathering; the upper zone is often greyish green in colour and contains traces of organic materials associated with the overlying wetland deposits. The clay deposit may be absent near the perimeter of the equalization storage basin because of its use for construction of a compacted clay liner.

A stratum of grey to red-brown silty sand and gravel is typically encountered beneath the silty clay and immediately overlying bedrock. The thickness of this layer generally ranges from 0.2 to 2.6 m.

North of the equalization storage basin, in the extreme northwest portion of the Industrial Area, is a narrow arm or "tongue" of low-lying terrain that was originally part of the low wetland area in the central portion of the site. This area contains about 0.6 to 1 m of yellow-

brown to orange to grey fine to coarse sandy tailings thought to be from early gold processing (Golder, 1988).

The low wetland area in the vicinity of the equalization storage basin and calcium arsenite stockpile is separated from the Moira River by a ridge of elevated bedrock that runs in a north-south orientation beneath the former primary treatment building. The area between the former primary treatment building and the Moira River was originally exposed to very shallow bedrock, which has subsequently been covered with 1.5 to 3.5 m of fill materials. Fill in this area consists mainly of very loose cinder and ashes, with traces of brick, gravel, and wood, and contains building rubble and debris. The fill materials are underlain either directly by bedrock or by a thin, discontinuous layer of silty sand and gravel over rock.

An approximate 1-m-thick layer of an organic silt deposit containing traces of a greyish-white substance resembling calcium arsenite was encountered by Golder Associates (Golder, 1988) along the Moira River in the vicinity of the former cobalt packing house.

The alignment of Old Westerly Creek is reported to have passed by the southwest corner of the castings building and discharged just northeast of the north nickel pond (Golder, 1988). Boreholes GA 18 and GA 20 are located in the vicinity of this alignment and encountered significant thicknesses of natural overburden overlying a depressed bedrock surface. Beneath slag or cinder fill, about 0.6 to 1.3 m of very loose sandy to silty alluvium and soft organic silt were encountered, followed by 0.8 to 2 m of very stiff grey to weathered grey-brown silty clay. This clayey soil has similar plasticity characteristics and moisture contents to those encountered onsite to the northwest. The clays are underlain by a layer of reddish-brown silty sand and gravel and what is assumed to be the bedrock surface where auger refusal was encountered.

Towards the southwest, the thickness of overburden is generally about 2.5 to 3 m; in the vicinity of the old equalization pond and the wetland to the west, the soil cover is generally about 1.2 to 1.5 m thick with some shallow bedrock areas and outcrops.

Adjacent to the northwest of the south nickel pond, a layer of soft greyish-white material was encountered (could not support the drilling equipment). The 1961 aerial photograph shows a relatively large area of white material at this location along the alignment of the diverted Old Westerly Creek. Chemical analysis of this material (Golder Associates Sample 25) indicated that it is probably lime residue from the treatment process in use at the time and contained arsenic (4.76 percent) and mercury (4,210 μg/kg). In the area west of the inactive ferric arsenate sludge lagoon is 1.2 to 1.8 m of fill consisting of clays, cinders and ash, brick, concrete, wood, and other building debris. Some soft white material was noted in Test Pit 9. The underlying native soil consists mainly of reddish-brown silty sand and gravel with some random cobbles and boulders, with its thickness controlled by the position of the underlying bedrock surface.

3.2.4 Hydrogeology

Groundwater flow at the Industrial Area is altered to some extent by constructed features such as abandoned underground mine workings, exploratory blasting, the cut-off barrier wall near the Moira River, drainage collection systems, and several ponds/lagoons.

Groundwater flows beneath the surface through overburden, bedrock, and/or a combination of both. In general, the groundwater flow direction is easterly and southeasterly toward

the Moira River. In the overburden, groundwater flows occur primarily through more permeable material usually lying directly on the bedrock surface. In the bedrock, groundwater flows occur primarily along fractures, bedding planes, and similar geological features. Fracture frequency and aperture generally decrease with depth and, therefore, groundwater flow through the bedrock is expected to be greater in the shallow bedrock. Bedrock flow patterns are influenced by zones of higher hydraulic conductivity associated with natural faulting and/or folding.

In the overburden, an apparent groundwater divide exists between the old lab building and the former primary treatment building. This divide is probably the result of groundwater being pumped from Pumping Station #5. If the pump does not run sufficiently long, the groundwater levels in the area of the equalization storage basin would likely rise enough for groundwater to flow southeast toward the Moira River.

A groundwater divide exists in the bedrock between the high ground at the former primary treatment building and the powerhouse to the north. East of this divide, groundwater flows more or less directly to the Moira River. West of this divide, groundwater flows in the bedrock along a longer flow path, eventually discharging to the Moira River at the southeast sector of the Industrial Area.

Figures 3-4 and 3-5 illustrate interpreted groundwater flow patterns in overburden and shallow bedrock, respectively.

3.2.5 Hydrology

The Moira River watershed, which includes the Deloro site, is comprised of an area of approximately 2,750 km^2 and flows from this watershed are discharged into the Bay of Quinte on the northern shore of Lake Ontario. Figure 3-6 shows the Moira River watershed area. The Moira River originates in an area of Precambrian rock about 100 km north of the Bay of Quinte. Precambrian rock is exposed at much of the surface in the northern part of the basin but is overlain by as much as 83 m of Palaeozoic sedimentary rocks consisting mainly of limestone, dolostone, shale, and sandstone in the southern part of the basin. Sand and gravel of glaciofluvial origin, as well as organic deposits, are the primary overburden materials in the northern half of the watershed while glacial till, glaciofluvial sand and gravel, and glacio-lacustrine sand, silt, and clay predominate in the southern portion of the watershed.

The Moira River flows through Wolf, Moira, and Stoco Lakes. The site is located approximately 20 km upstream of Moira Lake and is bisected by the Moira River. The majority of the buildings and former processing areas of the mine are located on the west side of the river (i.e. the Industrial Area), while the primary tailings disposal area is to the east of the Moira River and west of Young's Creek (i.e. the Tailings Area).

Bend Bay, a 21-ha widening of the Moira River, is located approximately 16 km downstream of Deloro and 3 km upstream of Moira Lake. Bend Bay is reported to have a mean water depth of 1 m and a residence time of 0.6 days. Moira Lake is essentially a shallow enlargement of the Moira River and is characterized by two distinct basins. The west basin has a surface area of approximately 200 ha, a mean depth of 4 m, and a maximum depth of 6 m. The east basin has a surface area of 600 ha, a mean depth of 4 m, and a maximum depth of 11 m. The residence time of water in Moira Lake is reported to range from 0.34 years to as long as 4.38 years in the summer (Kilborn, 1983). The west and east basins of Moira Lake

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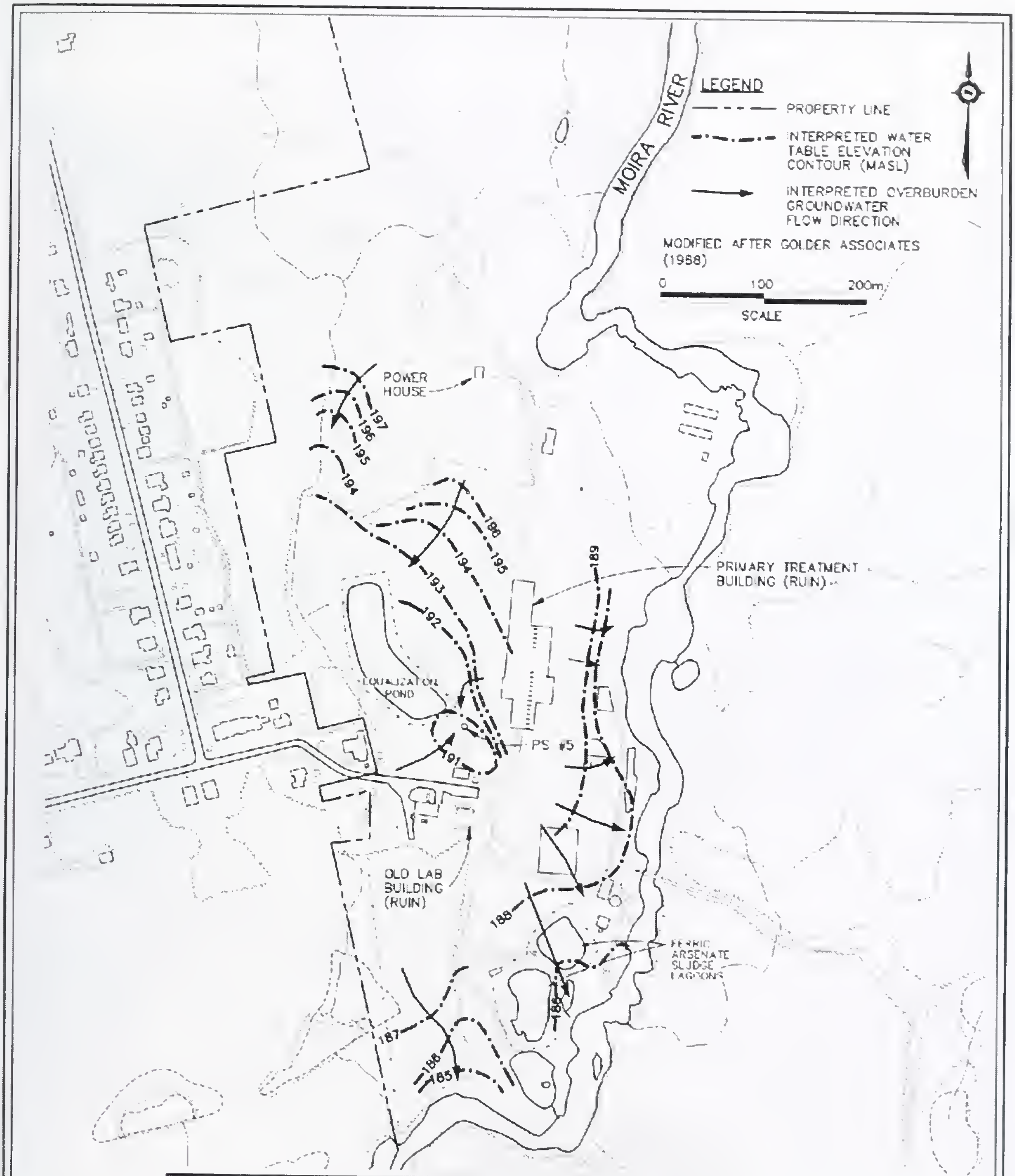

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DELORO MINE SITE CLEANUP

FIGURE 3-4
SHALLOW INTERPRETED WATER TABLE ELEVATION AND GROUNDWATER FLOW DIRECTION IN OVERBURDEN

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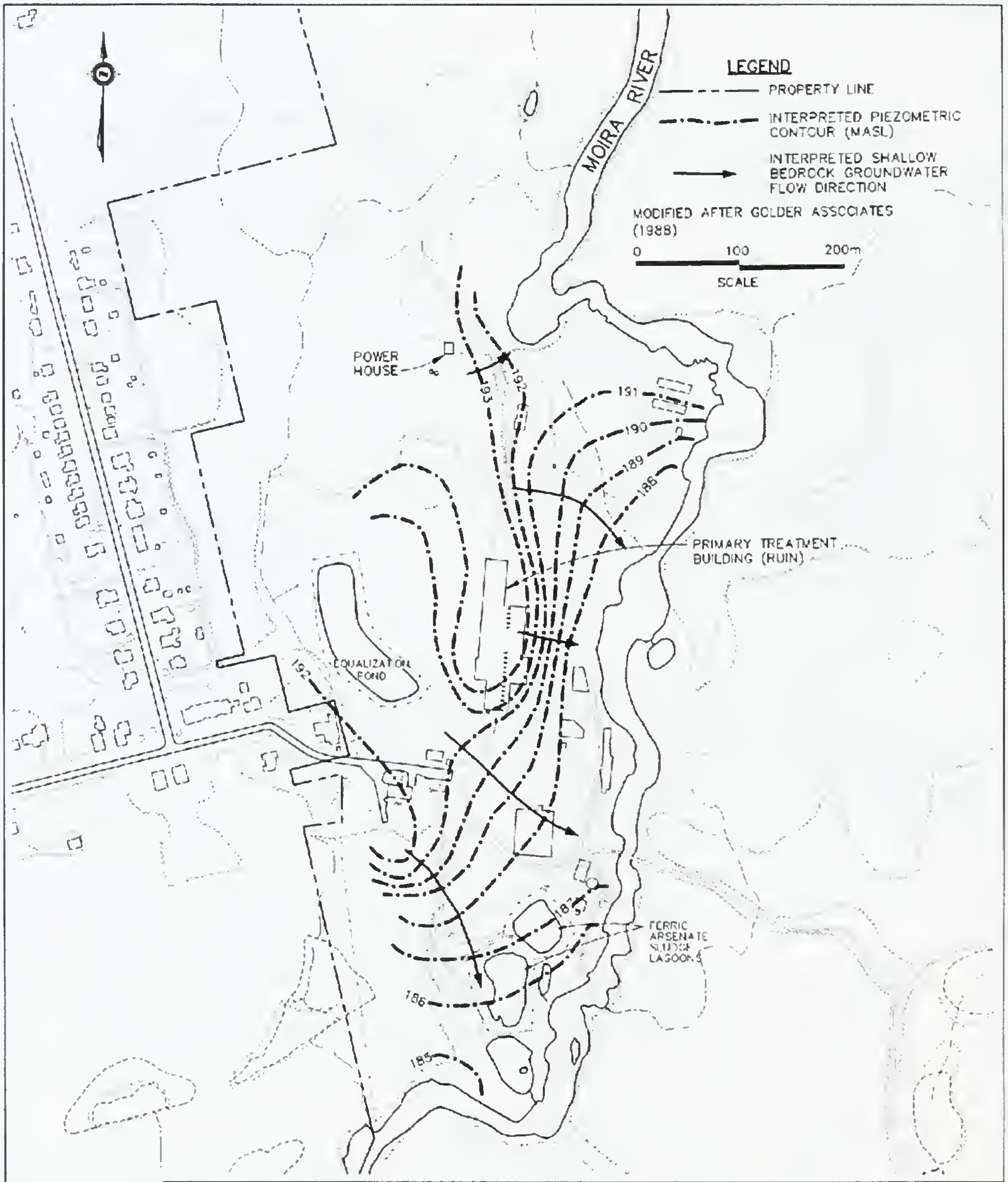

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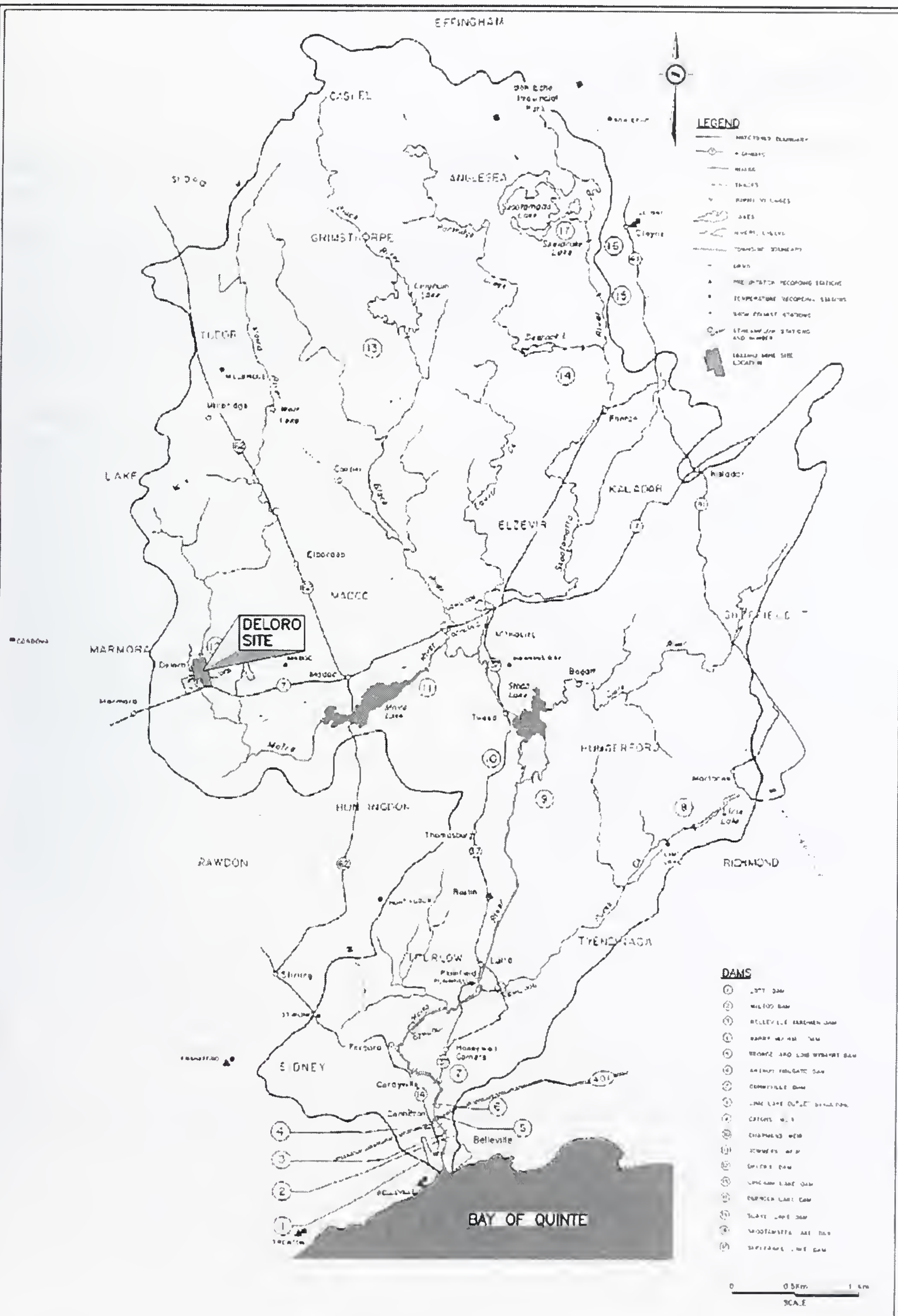
DELORO MINE SITE CLEANUP

FIGURE 3-5
INTERPRETED PIEZOMETRIC CONTOUR ELEVATION AND GROUNDWATER FLOW DIRECTION IN SHALLOW BEDROCK



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REHABILITATION OF THE DELORO MINE/REFINERY SITE

FIGURE 3-6
MOIRA RIVER WATERSHED AREA

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are considered to be well mixed during the spring and fall, but transient thermoclines develop during the summer at deeper locations within the two basins thus limiting vertical mixing. The Moira River represents the primary flow into and out of Moira Lake.

Water and Sediment Quality

Several assessments of the impact of past mining activities on water and sediment quality in the Moira River watershed have been made over the years with the majority focusing on arsenic, the primary contaminant of concern originating from the Deloro site. The most recent study was completed by Golder Associates and Global Tox International in 1999/2000 (Golder/Global Tox, 2001).

Floodplain Mapping

Floodplain mapping was performed along the Moira River from the former nickel ponds in the southwest end of the site, to upstream of the Deloro falls at the north end of the site (CG&S, November 1998). The "A" Shaft, Gatling Shaft caps, and the powerhouse on the north edge of the Industrial Area are significantly higher (at least 5 m) than the nearest water elevation. Therefore, flooding along the section upstream of the Deloro falls is not likely to have a significant impact on the site.

The floodplain modelling was performed using the BOSS HEC-2™ water-surface profile computation program. This program, based on an optimized version of the U.S. Army Corps of Engineers Hydrologic Engineering Center water-surface profile computation model HEC-2, is widely applied in floodplain management. It is capable of addressing sub-critical and super-critical flows and modelling the impact of bridges, weirs, culverts, and split-flow scenarios.

According to the Ontario Ministry of Natural Resources' *Floodplain Management in Ontario - Technical Guidelines*, the Deloro Mine Site lies in Zone 2. For watersheds within Zone 2, the regulatory flood is the 100-year flood level or a higher level that was recorded and documented. For the Deloro Mine Site, the 100-year flood was selected as the regulatory flood level.

Floodplain mapping was performed for the following storm flows:

2-year storm	→ 34.7 m^3/s
5-year storm	→ 42.2 m^3/s
10-year storm	→ 46.1 m^3/s
20-year storm	→ 49.2 m^3/s
50-year storm	→ 52.7 m^3/s
100-year storm	→ 54.9 m^3/s

These storm flows were calculated based on flow measurements at the Water Surveys of Canada gauging station (Station No. 02HL005) located 3.0 m south of the bridge at Highway 7.

The model was not calibrated because of the lack of water-level gauges in the vicinity. During the 100-year storm in 1981, the water level in the Moira River did not raise over the bridge on the Deloro site[3]. This fact was used as a check to make sure the model does not predict water flow over the bridge during a 100-year storm. Flow velocities for the 100-year storm flow are shown in Table 3.3.

[3] Telephone conversations with Mike Newland, Ontario Clean Water Agency, September 22 and 30, 1997

TABLE 3.3
FLOW VELOCITIES IN MOIRA RIVER FOR A 100-YEAR STORM FLOW

Cross Section Number (m)	Channel Mean Flow Velocity (m/s)	Cross Section Number (m)	Channel Mean Flow Velocity (m/s)
0	1.04	305	2.4
8	0.74	308	2.37
86	0.40	315	2.27
169	0.86	484	0.71
206	1.83	610	0.69
240	1.04	740	0.99
265	1.4	800	0.31
270	2.95	834	3.09
277	3.00	868	2.86
284	1.14	930	3.13
285	1.14	986	1.72
300	2.92	1,108	1.83
301	2.92		

The flood risk maps in Figures 3-7 and 3-8 show the 100-year flood boundary and the location of the cross-sections used in the floodplain model. The model predicts that in the event of a 100-year storm, the Tailings Area would remain above the flood waters of both the Moira River and Young's Creek. The active and inactive ferric arsenate sludge lagoons in the Industrial Area would also remain above the flood waters. However, the third inactive wastewater lagoon (south of the two ferric arsenate lagoons) is predicted to be under the 100-year flood waters. The floodplain for the Moira River tends to be narrow, except for the area immediately downstream of the mine site bridge (CG&S, November 1998).

3.3 Natural Environment

An ecological inventory of the Deloro Mine Site property was conducted during the summer of 1997 (CG&S, February 1999). The objective of the inventory was to characterize fish, vegetation and wildlife habitat on the site, to assess the habitat characteristics that contribute to the various assemblages found, and to detect the presence of significant species or groups of species that could constrain remediation options. The presence or absence of certain organisms was also used to provide preliminary information on whether there are qualitative effects of special materials at the site on fish, vegetation and wildlife. Readers are directed to the February 1999 report for specific results.

3.3.1 Aquatic Ecology

All watercourses within the vicinity of the Deloro Mine Site sampled for fisheries (which were all within the area of potential contamination associated with past historical mining activities) can be classified as fish habitat. These watercourses support a fishery that is economically important as bait and forage fish for higher trophic levels, and as game fish. Nineteen species were captured. These were typical of species common in the geographic area in warmer reaches of clear flowing streams and marshes. Ages ranged from young of the year to large adult fish, suggesting that spawning is occurring in these reaches. There were no threatened or endangered species of fish found. No evidence of water quality impairment can be derived from fisheries community sampling results (CG&S, February 1999).

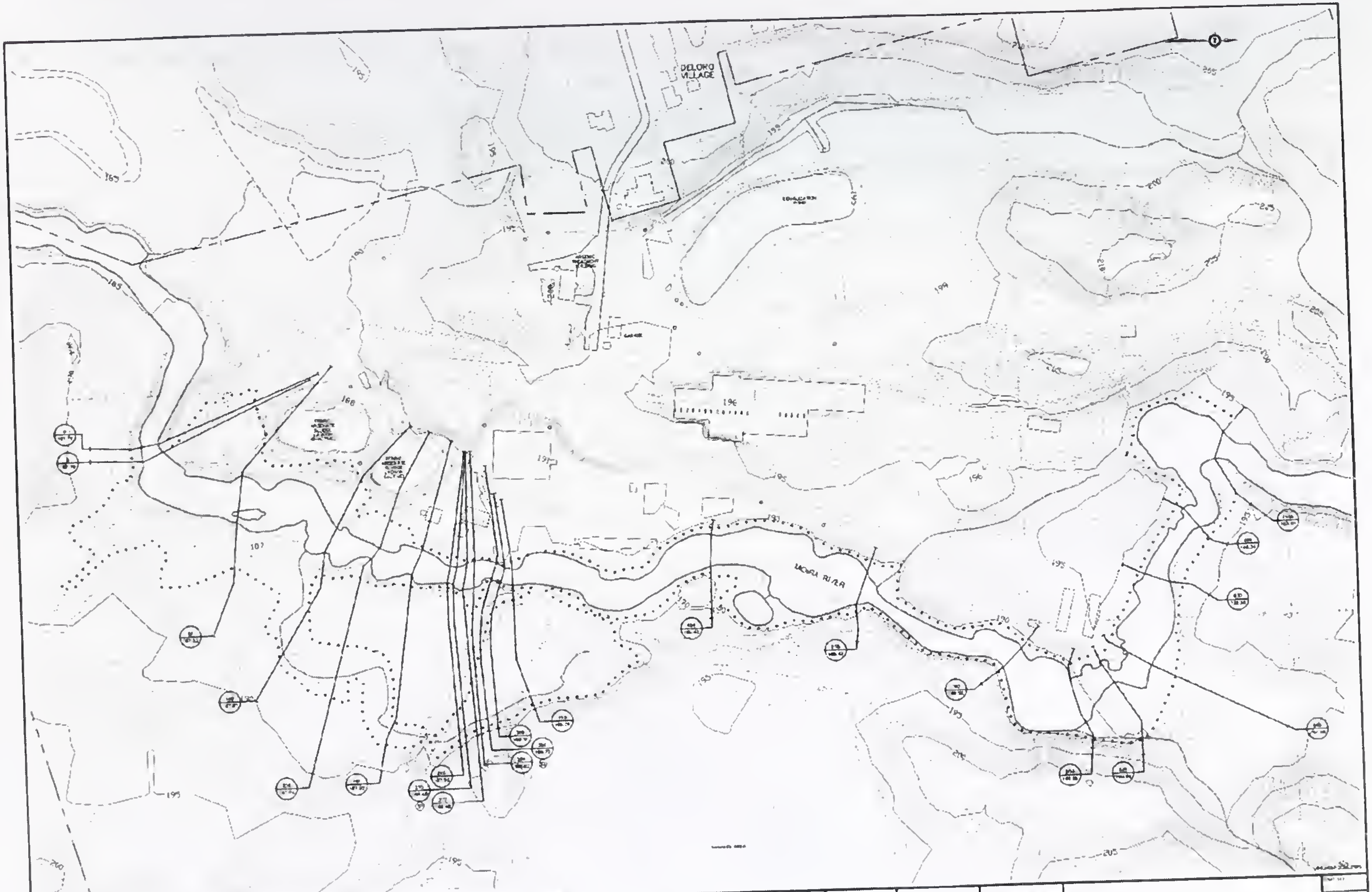

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FIGURE 3-7
FLOOD RISK MAP – MOIRA RIVER

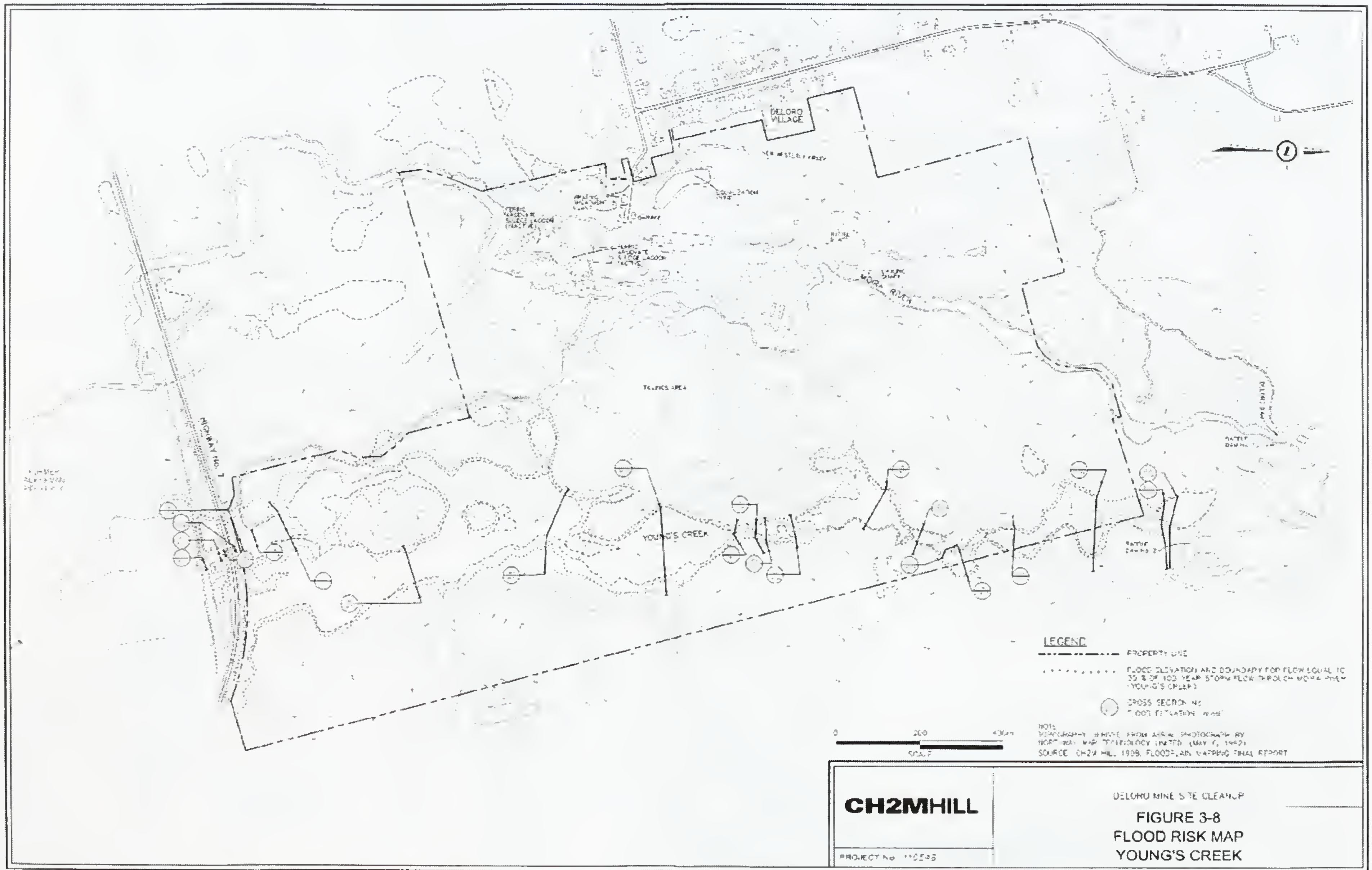

FIGURE 3-8
FLOOD RISK MAP
YOUNG'S CREEK

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3.3.2 Terrestrial Ecology

No rare plant communities were found on the site. Nor were there any rare, threatened or endangered species of plant or animal life found. The composition of plant communities was typical in quality for this location, intermediate between southern and northern Ontario climatic zones and levels of soil disturbance. Wildlife species were also typical of extensive forests in this area.

Waste arisings on the site may be degrading vegetation in some wetland communities, particularly in the west arm of Young's Creek; however, these conclusions are likely confounded by the effects of other disturbance in this part of Young's Creek, particularly by the removal of beaver dams along the Creek and consequent drying of soils. Plant and animal communities in other areas, whether they contained waste or not, were typical of the habitat in which they were found. Wildlife communities were primarily determined by the type of vegetation present. It was not possible to draw conclusions about the effect of special materials on plant communities in upland areas, or on wildlife (CG&S, February 1999).

Succession in remediated areas will likely proceed slowly in areas where bedrock is close to the surface, as these areas are nutrient- and moisture-deficient. Succession will likely proceed from early successional communities, such as the one found on the tailings cap, through more advanced successional communities, which will ultimately be determined by soil conditions, microclimate and surrounding vegetation. It is recommended that native species currently found in soils over bedrock be used for restoration after remediation as they are well adapted to these conditions.

3.4 Contaminants in Industrial Area and Contaminant Loading

3.4.1 Development of a Water Balance and Load Model

A water balance was developed for the Industrial Area based on consideration of the key elements in the water cycle and the sources and sinks of water resulting from ongoing remedial activities at the site. This effort was focused on the north/central portion of the Industrial Area on the west bank of the Moira River. This area contains the calcium arsenite stockpile and the existing groundwater collection system. Previous investigation in this area is considered to provide sufficient data to support development and calibration of a water balance. The main components of the water balance are discussed below.

Inputs

Precipitation. The annual precipitation in the vicinity of the site is recorded as 889.6 mm based on measurements at the Tweed meteorological station (Golder, 1988).

Evapotranspiration. Evapotranspiration was estimated by Golder (1988) at 584.7 mm/yr, or 65.7 percent of precipitation using the Thornthwaite method. An independent estimate using the Penman method estimated evapotranspiration at 62.1 percent of precipitation. A third method of estimating evapotranspiration from the difference between precipitation and runoff over the area of the Moira River basin upstream of Highway 7 resulted in an evapotranspiration equal to 57 percent of precipitation. It was concluded that evapotranspiration values of 57 to 66 percent of precipitation represented the range of

evapotranspiration values likely to be encountered at the Deloro site, a range typical for Southern Ontario, based on work at other project sites (CH2M HILL, March 2002a).

Infiltration. The difference between precipitation and evapotranspiration is available for either infiltration to the ground below the root zone as recharge to groundwater, or as runoff to local water courses. The relative amount of infiltration is thought to be largely influenced by the topography and the permeability of ground surface cover. Typical infiltration values for this area of the province range from 10 to 20 percent of precipitation (Ministry of Natural Resources, 1984); however, accurate estimations of infiltration rates are not readily developed or measured. Conditions of the Industrial Area and sections of the Mine Area appear to be similar and are ideal for surface water runoff, and to a lesser extent infiltration, due to the construction rubble, coarse soils, and lack of vegetation. The characteristic soil type in Deloro and the surrounding catchment area, according to Agriculture Canada (Soils of Hastings County, 1987), is Deloro Soil, which provides good drainage. It was assumed that infiltration ranges from 10 to 20 percent of precipitation for the section of the site located on the west bank of the Moira River (CH2M HILL, March 2002a).

Groundwater Inflow. In addition to infiltrating recharge water, groundwater also flows beneath the central Industrial Area from upland areas to the west and north. This flow occurs primarily through a permeable stratum of silty sand and gravel that overlies bedrock throughout much of the site, and through fractured bedrock.

This groundwater inflow was subsequently estimated by considering infiltration over the area of the Moira River watershed from the river, west through the Deloro site to the western boundary of the watershed. This resulted in an estimated drainage area of 2,400,000 m^2, of which 400,000 m^2 is the Deloro site catchment area. The entire 2,400,000 m^2 area was considered for infiltration in this water balance. Refer to the report: *Development of a Sitewide Water and Load Balance* (CH2M HILL, March 2002a) for the delineation of the Deloro Catchment Area and the Moira River Watershed Area.

Run-on. It was assumed that there was no surface water run-on from upgradient areas to the Deloro site. The absence of surface water run-on from upgradient areas beyond the immediate vicinity of the site catchment area is considered appropriate as New Westerly Creek was developed from a ditching system on the westerly property line, and it is expected that most run-on will be intercepted by this ditch (CH2M HILL, March 2002a).

Outputs

Groundwater outputs from the site fall into two categories: (1) naturally occurring discharges and (2) water collection systems.

Naturally Occurring Discharges

Runoff. No previous attempts were made to determine surface water runoff from the site. Runoff was estimated as the difference between evapotranspiration and infiltration. This resulted in a range of runoff values of approximately 19 to 33 percent of precipitation. Runoff values in the higher portion of this range were selected, as the site is well graded with minimal potential for pooling, in addition to the other conditions that promote runoff previously described. The runoff is estimated at 30 percent, which falls within this range of runoff values (CH2M HILL, March 2002a).

Industrial Area Groundwater. An extensive evaluation of site hydrogeology and groundwater conditions was undertaken by Golder (1988) for the Industrial Area. The results of this evaluation formed the basis for the development of groundwater discharge estimates from the west bank to the Moira River (CH2M HILL, March 2002a). Using Golder's measured hydraulic conductivity values (arithmetic averages), representative hydraulic gradients and measured media thicknesses and lengths along the Moira River, separate flow rates were calculated for overburden (1,177 m^3/yr), for bedrock excluding the cut-off wall (5,839 m^3/yr), and for bedrock beneath the cut-off wall (3,284 m^3/yr). The majority of the groundwater flow in the Industrial Area overburden is toward the river, but a portion of the flow near the equalization storage basin is toward a pumping station (PS#5). All of the bedrock flow in the Industrial Area is toward the Moira River.

Mine Area Groundwater. Hydrogeological calculations in the 1998 investigation into the Mine Area in the vicinity of the Tuttle Shaft (CG&S, August 2001) provided a range of values for groundwater flow from the Mine Area to the Moira River, based on possible hydraulic conductivities of the subsurface material. Mean values were used for the water balance, with the groundwater flow from the overburden averaging 5,624 m^3/yr and the groundwater flow from the bedrock averaging 3,157 m^3/yr (CH2M HILL, March 2002a).

Tuttle Shaft Gravity Flow. The Tuttle Shaft flows by gravity under artesian conditions to the Moira River, typically for nine months of the year. A peak value of 135 L/min was measured during 1997 investigations (CH2M HILL, March 2002a).

Water Collection Systems

Groundwater Collection System. The Ontario Clean Water Agency (OCWA) operates a groundwater collection system in the Industrial Area on behalf of the MOE. Records of monthly withdrawals based on pumping hours are available in the form of annual records of water taking. These records of water withdrawals were evaluated in the report: *Development of a Sitewide Water and Load Balance* (CH2M HILL, March 2002a). An annual average withdrawal of 111,481 m^3/yr was determined.

Tuttle Shaft Collection. OCWA also operates a pumping system to collect contaminated groundwater from the Tuttle Shaft during low-flow periods in the summer, typically for three to five months. An annual record of water taking has been prepared each year, which includes an estimate of the withdrawal based on pump hours and pump capacity. These data were evaluated in the report: *Development of a Sitewide Water and Load Balance* (CH2M HILL, March 2002a). An annual average withdrawal of 20,763 m^3 was determined for the period from 1991 to 1995 (the 1996 values are anomalous).

Water Balance Analysis

A water balance within 1.4 percent was achieved using infiltration estimates of 10 percent for the Industrial Area and 15 percent for both the rest of the Deloro catchment area and the area of the Moira River watershed contributing to groundwater inflow over a greater depth.

A number of important observations were evident from the water balance, as follows:

- A significant percentage of water (85 percent) passing through the west bank of the Deloro site was due to groundwater inflow
- Over 42 percent of the discharge from the west bank was due to water collection systems

- The groundwater collection system was the largest output from the site (36 percent) for the Industrial Area
- Surface water runoff was the second-largest output (34 percent)
- Groundwater seepage was a small component of discharge from the site (6 percent)

A limited sensitivity analysis was undertaken to evaluate the sensitivity of the water balance error to several of the key assumptions; this can be reviewed in the report: *Development of a Sitewide Water and Load Balance* (CH2M HILL, March 2002a).

3.4.2 Loading Estimates

A load balance was developed to provide an indication of the relative amounts of contamination released from various portions of the site in terms of mass per unit time. Arsenic was originally selected as an index of contamination and loading estimates were developed in units of kilograms per year (kg/yr). This approach proved to not fully represent the extent of the contamination; so, in addition to arsenic, both cobalt and copper were considered for this updated load balance. As described in the Development of Closure Criteria Report (CG&S, October 1998a), contaminants of concern were determined based on the average annual contaminant concentration for three years of monitoring (1994-96) using the current Provincial Water Quality Objectives (PWQO). A calculated index above unity indicated that, on average, the contaminant under consideration was above the lowest of the current or interim PWQO for the three-year period. While this comparison resulted in several contaminants being above unity, arsenic, cobalt, and copper are the most significant with respect to exceedance of current and proposed regulatory criteria. Refer to the report entitled *Deloro Mine Rehabilitation Project, Development of Closure Criteria* (CG&S, October 1998a) for further clarification on the selection of the contaminants of concern. Refer to the *Development of a Sitewide Water and Load Balance* (CH2M HILL, March 2002a) for the approach used to develop the load estimates.

West Bank

The data to support development of loading estimates for the west bank of the Moira River is relatively well defined based on the water balance and the extensive monitoring network in this area. However, the available data do not provide complete characterization of runoff quality from the site. An average arsenic concentration of 2.47 mg/L measured at Station 320, located just south of the Industrial Area, for 1994 to 1996 was used as the best indicator of surface water runoff quality. However, this area is suspected to be diluted relative to runoff from the Industrial Area. Accordingly, the arsenic concentration in runoff from the central Industrial Area may be higher and was assumed to be 12.8 mg/L or approximately five times the levels observed at Station 320 in order to achieve a mass balance (CH2M HILL, March 2002a).

According to the assumptions made, the loading for each of the three contaminants from the west bank was as follows:

- Arsenic – 3,391 kg/year, 66 percent from bedrock flow beneath the cut-off wall
- Cobalt – 57 kg/year, 46 percent from the surface water runoff
- Copper – 8 kg/year, 74 percent from surface water runoff

Refer to the report: *Development of a Sitewide Water and Load Balance* (CH2M HILL, March 2002a) for a more detailed account of the rationale behind these loading estimates and their justification.

3.4.3 Industrial Area Materials

A waste inventory was developed and submitted as part of the Golder Associates report (Golder, 1988). This waste inventory is briefly summarized below.

Calcium Arsenite

A white powdery substance, characterized as calcium arsenite, has been stockpiled in an area to the east of the equalization storage basin. The pile has been covered by a thin layer of crushed slag (approximately 100 mm) to reduce wind erosion. The cover layer is discontinuous and calcium arsenite is exposed to the elements in several areas. A Golder Associates (Golder, 1988) analytical result shows that the white amorphous material found in borehole GA12 north of the slag covered arsenite pile, was also calcium arsenite. Vegetation in this area is, for the most part, non-existent or is stressed. A significant 1-m deposit of calcium arsenite was found under a 2-m layer of fill. A review of aerial photographs indicated this location to be a former dump site. The extent of the site was proportional to the south arm of the slag-covered calcium arsenite stockpile. Considering the numerous locations where calcium arsenite was observed, both above and below ground surface, it is assumed that the white powdery substance may be present at numerous, unknown discrete locations throughout the Industrial Area.

Slag

A by-product of the smelting and refining process is a hard glass-like material known as slag. According to Golder Associates (Golder, 1988), an estimate of the volume of this slag present in the ridge to the west of the castings building is 8,000 tonnes. The actual amount of slag in the ridge is more likely to be near 12,000 to 14,000 tonnes. These estimates may be low as they do not consider the volumes used to construct the riverbank and other fill locations. The slag's composition includes one percent cobalt and arsenic ranging from 0.11 to 1.03 percent. Other constituents include calcium, silicates, and iron. Refinement of radioactive ores from the former Eldorado Nuclear Limited facility in Port Hope and other sources has resulted in varying amounts of radioactive slag being spread in locations throughout the site. The radioactive material is discussed further in some of the following paragraphs.

Ferric Arsenate Sludge

The wastewater treatment plant at the Deloro site produces in the range of 800 m^3 per year of a red filter cake sludge composed mostly of ferric arsenate. The ferric arsenate is pumped into a settling lagoon where it is dewatered naturally and stored until disposal is arranged. The sludge contains approximately six percent solids as it enters the lagoon (I.E.C. Beak, 1984). The ferric arsenate sludge lagoon is located in the southeast portion of the Industrial Area just south of the mine site bridge. The southern ferric arsenate sludge lagoon has been taken out of service but contains an unknown volume of sludge that will need to be removed. The sludge has a 10 to 15 percent concentration of arsenic with the remainder of the sludge being composed of calcium, iron, and chloride (Witteck, 1986).

Building Rubble

The demolition of site buildings has created large rubble piles throughout the Industrial Area. Large quantities of rubble consisting mostly of wood, concrete, and brick were used as fill in several locations. The most significant amounts of this waste are located in the central region of the Industrial Area. From a site investigation, the rubble located in the area of the former laboratory building is mostly composed of wood with some red brick and clay tile. The former men's dry building area contains cinder blocks and wood waste. The former arsenic packing house is similar to the laboratory building. The area contains mostly wood waste with a small amount of brick and the remnants of an overhead sprinkler system. The former extension to the castings building has a large quantity of wood waste with brick and metal columns and joists. The ruins of the former cobalt packing shed are resting on a concrete slab at the edge of the Moira River. They consist of wood waste and brick.

Gold Mine Tailings

Sandy yellow/orange mine tailings were produced as a result of the early gold mining operations. Some of these tailings were disposed of in the low-lying wetland areas northwest of the equalization storage basin. The mass of gold tailings is estimated at 15,000 tonnes. They consist of finely ground quartz with sulphur and cyanide. Chemical testing of the tailings reveals a 4.5 percent arsenic concentration and a mercury concentration of 0.67 mg/L.

Miscellaneous Wastes

Several miscellaneous wastes (e.g. box inspection holes and metal storage tanks) are present at various locations on the mine site. Two concrete tiles have been abandoned in the southwest portion of the Industrial Area. The former dump site at the extreme south of the Industrial Area contains various metal wastes such as filings, cast iron wheels, rail ties, steel rails, crushed barrels, crushed brick, miscellaneous wood waste, and asbestos sheets (i.e. siding material). Metal scrap pieces line the west bank of the Moira River at the south end of the Industrial Area. The ruined walls of the boarding house foundations contain a large quantity of steel barrels. Thin layers of lime containing arsenic were discovered along the Moira River shoreline directly east of the former cobalt packing shed.

Radioactive Materials

Extensive surveys of the extent and character of the radioactive materials on the Deloro site have been conducted by the Atomic Energy Control Board (AECB), (1979[4]), the Ontario Ministry of Labour (MOL), (1986[5]), Golder Associates (Golder, 1988), and SCIMUS Inc. (CG&S, June 1999). A review of existing information on the radioactive materials on the site showed that high radiation fields and high radium concentrations were associated with radioactive slag, concentrated mainly on the slag pile. The 1979 AECB study conducted analyses of several slag samples and found radium concentrations to vary from 0.04 Bq/g to 18.5 Bq/g. The MOL (1986) radiation field surveys across most of the site showed areas of high radiation fields (>1.5 µSv/h or 250 µR/h), mainly at the slag pile in the vicinity of the old lagoon south of the present treatment plant, in some areas around the north and south lagoons, and in localized areas in the northern part of the red mud tailings pile. In 1988, Golder Associates conducted analyses of two soil samples collected in the vicinity of the old

[4] AECB, 05/05/79, referred to in Golder and Associates, "Hydrogeological Investigation Refinery Site Rehabilitation, 1988, Appendix III

[5] MOL, 1986, Ontario Ministry of Labour, Field Site Visit, October 7, 1986

lagoon exhibiting high radiation fields. These samples had radium concentrations of 90 and 70 Bq/g. The source or nature of the radioactive soil was not described (Golder, 1988). The recent investigations (CG&S, June 1999) were intended to re-survey the areas exhibiting high radiation fields greater than 0.5 µSv/h or 83 µR/h at 1 m above ground surface to better delineate the nature and extent of the radioactive contamination on the Deloro site. The areas that would likely require special consideration during remediation (i.e. removal for consolidation or in-situ remediation) were staked out on the site and are indicated on Figure 3-9.

The survey indicated that there were two types of radioactive materials onsite, a radioactive slag and a tailings-like material (the Golder Associates soil samples).

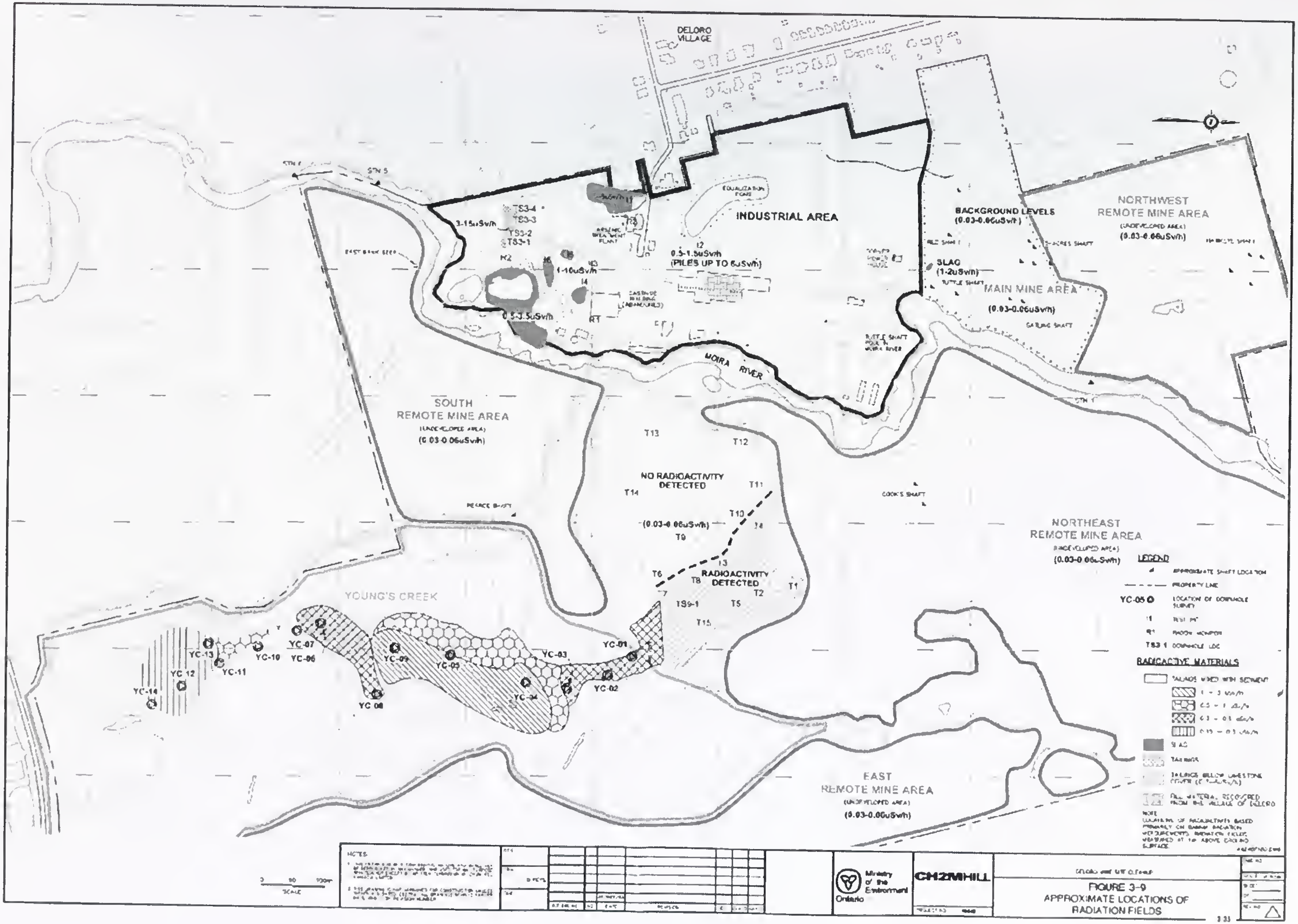
Radioactive Tailings. As mentioned above, high radiation fields were observed during the MOL survey in 1986 in the southern portion of the Industrial Area in the vicinity of an old lagoon. The 1988 Golder Associates study identified two tailings-like samples of material from this area with radium contents of 70 and 90 Bq/g. CH2M HILL (formerly CG&S) surveyed this area during its evaluation and radiation fields up to 80 µSv/h or 13,333 µR/h (on contact) were observed. The radioactive tailings-like samples were light brown with a granular consistency similar to that found in uranium tailings. Samples were taken for radium analysis and the results are shown in Table 3.4. Several downhole logs were made in this area to determine the vertical extent of the radioactive soils (CG&S, June 1999).

TABLE 3.4
RADIUM CONTENT OF SOIL SAMPLES

Sample Number	Sample Location	Radium Content (Bq/g)	Radium Content (pCi/g)
TS3-1	Old Lagoon at TS3-1	397	10,719
TS3-2	Old lagoon at TS3-2	16.3	440
TS3-3	Old lagoon at TS3-3	20.6	556
TS9-1	Red Mud tailings at Test Pit T1	74.6	2,014
TS9-2	Red Mud tailings at Test Pit T1	155	4,185
TS9-3	Red Mud tailings at Test Pit T1	0.063	1.7
TS5-1	Slag pile at Test Pit I3	3.25	88

Radioactive Slag. The radioactive slag appears to be concentrated in two areas on the southeastern and eastern portions of the slag pile. Most of the slag pile is non-radioactive with background radiation fields. The radioactive slag is piled on top of other slag and seems to have been deposited last on the pile. Radiation fields vary from 1 µSv/h or 167 µR/h to 10 µSv/h or 1,667 µR/h (CG&S, June 1999).

The slag appears to have been used as fill material throughout the Industrial Area. The areas with the largest accumulations and highest radiation fields are indicated on Figure 3-9. Radiation fields in the areas of slag fill are generally about 0.5 µSv/h or 83 µR/h; however, in some areas, they range up to about 6 µSv/h or 1,000 µR/h. The regions with the highest radiation fields are localized; however, even those areas with 0.5 µSv/h or 83 µR/h fields could have slag emitting higher fields underneath. Six test pits were excavated in the slag material with a backhoe to evaluate this concern. A backhoe was used because drilling in this material was not possible using the hand auger used for the downhole gamma probe (CG&S, June 1999).


DELORO VILLAGE
INDUSTRIAL AREA
0.5-1.5uSv/h
(PILES UP TO 6uSv/h)
3-15uSv/h
TS3-4
TS3-3
TS3-2
TS3-1
1-10uSv/h
0.5-3.5uSv/h
RT
BACKGROUND LEVELS
(0.03-0.06uSv/h)
SLAG
(1-2uSv/h)
MAIN MINE AREA
(0.03-0.06uSv/h)
NORTHWEST
REMOTE MINE AREA
(0.03-0.06uSv/h)
MOIRA RIVER
SOUTH
REMOTE MINE AREA
(0.03-0.06uSv/h)
T13
T12
NO RADIOACTIVITY
DETECTED
T14
T11
T10
(0.03-0.06uSv/h)
T9
T6
T8
RADIOACTIVITY
DETECTED
T1
T2
TS9-1
T5
T15
NORTHEAST
REMOTE MINE AREA
(0.03-0.06uSv/h)
YOUNG'S CREEK
YC-07
YC-06
YC-09
YC-05
YC-03
YC-01
YC-02
YC-04
YC 08
YC-13
YC-10
YC-11
YC 12
YC-14
EAST
REMOTE MINE AREA
(0.03-0.06uSv/h)
LEGEND
YC-05
RADIOACTIVE MATERIALS
SCALE
Ministry of the Environment
Ontario
CH2MHILL
FIGURE 3-9
APPROXIMATE LOCATIONS OF
RADIATION FIELDS

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Test Pit I1 showed that the slag fill material was about 2.0 m deep with the radioactive slag in only the upper 0.3 m with contact radiation fields up to 10 μSv/h or 1,667 μR/h. Test Pit I2 indicated that the slag fill was about 1.0 m thick, the bottom 0.3 m being mixed with soil. Radiation fields varied between 0.5 μSv/h and 1.5 μSv/h (83 to 250 μR/h) (CG&S, June 1999).

Test Pits I3 to I5 were dug on top of the slag pile. Test Pit I3 was dug into a very small localized area of an elevated radiation field of 1 to 2 μSv/h or 167 to 333 μR/h. The backhoe uncovered a cache of bags of what looked like crushed slag. A sample was taken and sent to the Low-Level Radioactive Waste Management Office (LLRWMO) in Port Hope for radium analysis. The results of the analysis are shown in Table 3.4. A radium concentration of 3.25 Bq/g (88 pCi/g) was measured. Test Pit I4 was dug in a section of the slag pile with background radiation fields to determine if radioactive slag was underneath the surface. Large pieces of slag were encountered within the first metre. There was no evidence of radioactive slag under the surface. Test Pit I5 was dug in a larger but localized area of high-radiation fields on the top of the slag pile. It was determined that the radioactive slag was mainly on the surface of the pile, within the upper 0.3 m (CG&S, June 1999).

Test Pit I6 was dug in the roadway at the southern end of the slag pile adjacent to the old treatment plant. The purpose of this test pit was to determine whether the elevated radiation fields in this area originated from the radioactive slag on the slag pile directly adjacent or whether there was radioactive slag fill in the roadway. Upon digging, radiation fields increased with depth, indicating the presence of radioactive slag in the roadway. High radiation fields were measured to a depth of more than 0.6 m (CG&S, June 1999).

Radiation surveys were conducted in the vicinity of the Gatling and Tuttle Shafts, as well as at a dump site near the river in the vicinity of these shafts. Background radiation fields (0.03 to 0.06 μSv/h or 5 to 10 μR/h) were measured in all areas except one small localized area beside the road near the powerhouse where some radioactive slag was used for fill material (CG&S, June 1999).

The re-survey of the radioactive slag in the Industrial Area confirmed past results. The source and largest accumulation of the radioactive slag was found to be deposits of radioactive slag on the surface of the slag pile, particularly in the eastern and southeastern portions. Most of the slag pile was non-radioactive. A mix of non-radioactive and radioactive slag was used as fill material throughout the Industrial Area. In most areas, radiation fields are less than 0.5 μSv/h or 83 μR/h, but in localized areas fields are higher. The depth of the radioactive slag fill varies from 0.3 m to greater than 2.0 m (CG&S, June 1999).

3.5 Social Conditions

The Industrial Area is part of the larger Moira River watershed; therefore, any impacts attributed to the Industrial Area could consequently impact the social conditions associated with the Moira River. The Industrial Area is located in the old Township of Marmora and Lake[6], on the west bank of the Moira River. The Moira River flows to the south and east into Moira Lake and Stoco Lake and, from there, south to the Bay of Quinte. The Tailings Area is

[6] The recent amalgamation has changed the jurisdiction this township falls under

located between and immediately adjacent to the Moira River and Young's Creek (Figure 1-1).

The land use along the Moira River within the old Township of Marmora and Lake is primarily zoned as environmentally protected areas, with the surrounding land uses primarily zoned as rural. Development along the Moira River and Young's Creek, from Deloro to Moira Lake, is generally sparse. The Moira River Conservation Authority indicated that 11 houses and three farms are adjacent to this section of the Moira River. Nine of these houses are located at the mouth of the river at Moira Lake.

Use of the Moira River, Young's Creek and Moira Lake within the old Township is primarily recreational, consisting of fishing and boating. Potable water within the Township is obtained primarily via private wells. Discussions with the Moira Lake Property Owners' Association also indicated that most landowners in the area are aware of the concerns associated with water quality, and consequently there are no potable uses of river or lake water. There appears to be very little agricultural land near the Moira River, Young's Creek or Moira Lake. Consequently, use of the river or lake for agricultural purposes is also unlikely. Readers are directed to the *Survey of Moira River Water Use – Update,* Final Technical Memorandum (CG&S, October 1998c) for further details.

4. Alternatives Evaluation Process

4.1 Strategic Direction for Site Cleanup

In the early 1990s, MOE staff from Southeast Region (now MOE Eastern Region) reviewed the Deloro Mine Site Project with the then MOE Management Committee to determine a strategic direction for final site cleanup. The Committee was composed of several MOE Assistant Deputy Ministers (ADMs), the Deputy Minister (DM) and the Minister, as well as an ADM and Director from the Ministry of Northern Development and Mines (MNDM).

Based on a detailed analysis of site conditions and on previous experience gained in similar situations, the Committee recommended that onsite waste management options be favoured as primary remediation techniques to rehabilitate the site. The main reason for adopting this approach was the realization that complete cleanup to natural background levels would be extremely costly and may not represent the most prudent expenditure of public funds. It was also recommended that the cleanup work proceed under an exemption to the provincial Environmental Assessment Act. These two recommendations were endorsed by the Ontario Minister of the Environment in October 1991 and funds were then allocated to retain professional services to develop and implement a cleanup plan under the authority of the MOE. The latter recommendations were identified as "fundamentals" in the *Deloro Rehabilitation Plan* produced by the Southeast Region office of the MOE (now the Eastern Region office of the MOE) in September 1992 and formed an integral part of the request for proposal that was issued by the MOE in 1996 to select a consulting engineering firm to develop and implement a remedial plan for the Deloro Mine Site.

4.2 Closure Objectives

As described in the report entitled *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a), and in the above section, the strategic direction for site cleanup involves onsite management of wastes through isolation and containment methods as primary remediation techniques. Consequently, a pragmatic approach has been adopted where mitigative measures are directed at risk reduction. This translates into the following project objective:

> *To successfully rehabilitate the Deloro Mine Site to mitigate any unacceptable impacts on human health or the environment in compliance with relevant environmental policies and regulations*

To satisfy this objective, specific site-wide and distinct area closure objectives were developed. The site-wide closure objectives are as follows:

1. Reducing the loading of arsenic and other contaminants to the Moira River
2. Compliance with appropriate regulations and policy
3. Satisfy the general intent of the Mining Act and related draft regulations
4. Reducing/controlling impact/risk to acceptable levels
5. Demolition of unneeded buildings to ground level

6. Prioritizing remedial action implementation according to risk reduction
7. Minimizing perpetual operation and maintenance
8. Restoration of the site to reflect its natural surroundings
9. Securing the site for the indefinite future
10. Managing the wastes over the smallest possible area

These site-wide closure objectives were further refined into area-specific closure objectives for each of the areas of the site. The area-specific closure objectives for the Industrial Area are presented in Section 5.1.

4.3 Overview of the Process to Generate and Evaluate Alternatives

The process applied by CH2M HILL to generate potential remedial alternatives for all areas of the Deloro site is illustrated in Figures 4-1 to 4-3. Initially, conceptual remediation methods that could have addressed some or all of the issues identified for each respective area of the site were identified. For instance, a method may address groundwater issues but not impacted sediment. These methods were evaluated with a screening process to identify which methods had the greatest potential to address the issues at the site, either alone or in combination with other methods. Improbable methods that did not have significant potential to contribute to a viable solution were eliminated early in the process. This resulted in a list of primary remediation methods that were retained for further evaluation.

The primary remediation methods were combined with enhancing features based on the judgement and experience of the project team to create a number of comprehensive remediation alternatives that addressed all of the environmental issues at the site. These comprehensive remediation alternatives were subsequently evaluated in a two-step process. The screening level evaluation again served to eliminate comprehensive remediation alternatives (as opposed to conceptual remediation methods that have been previously screened) that were unlikely to meet all of the remediation needs for the area. This second level of screening led to a short list of comprehensive remediation alternatives that were the subject of a more detailed evaluation. The detailed evaluation led to the identification of a recommended remediation alternative, which would be developed further and subsequently implemented to address the environmental issues at the site.

4.4 Generation of Comprehensive Remediation Alternatives

Significant efforts were invested through the years to characterize environmental conditions (i.e. soil, surface water, groundwater, air, human health risk, and ecological conditions) for all areas of the site. Such characterization studies were necessary to identify contaminants of concern, quantify contaminant concentrations and volumes, determine the media into which the contaminants were found, and assess contaminant mobility. It is as a function of these characteristics that potential conceptual remediation methods were initially generated.

The alternatives generation process involved consideration of the strategic approach described in Section 4.1, identification of conceptual remedial methods that CH2M HILL has either used on similar projects in the past, or identified in the scientific literature for the

contaminants and media of concern, as well as specific exclusionary criteria dealing with the following:

- Effectiveness of the conceptual methods in question to remediate the site
- Satisfaction (in principle) of government regulations and guidelines
- Pre-established design closure criteria

These criteria were designed to eliminate improbable conceptual remediation methods early in the process so that valuable time and resources were not expended in the completion of a more detailed evaluation.

The methods developed for consideration were not intended to be an exhaustive evaluation of all conceivable methods, but a focused assessment of readily identifiable and proven methods that had good potential for successful application at the site. Consideration of experimental or developmental methods was considered beyond the scope of this evaluation. Professional judgement and practical considerations factored into the range and diversity of methods considered. For instance, where a proven and effective method was readily identifiable and cost-effective, limited consideration was made of other methods.

The first exclusionary criterion, the effectiveness of the conceptual remediation method, was used to evaluate the expected effectiveness of the method in solving the problem identified for the area (i.e. Can the conceptual remediation method contribute to a significant attenuation of unacceptable impacts on human health or the environment by way of reducing a component of the contaminant load?). The second criterion, the satisfaction of government regulations and guidelines, served to evaluate the capacity of the conceptual remediation method to meet relevant government legislation and guidelines. The third criterion, design closure criteria, was used to assess whether the conceptual remediation method was likely to satisfy the area specific design criteria, a combination of the closure criteria and remediation targets outlined below.

These design criteria were developed from a risk based approach that is summarized in the report entitled *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a). The risk based approach was used to identify areas of the site that pose the greatest risk and consequently served to prioritize remedial action to obtain the greatest reduction of contaminant release from the site as well as overall exposure to contaminants. Using risk assessment, remediation targets were set as follows:

1. Surface water from Young's Creek and the Moira River should satisfy, on average, the Interim Provincial Water Quality Objectives (PWQO) for three key contaminants (i.e. arsenic, cobalt and copper) at the Highway 7 crossing located approximately 600 m downstream (i.e. south) of the site.
2. Post-closure onsite arsenic concentration in air and soil should be, on average, below a concentration that will ensure that the probability of incremental lifetime cancer risk for onsite workers and potential recreational users of the site is less than 1:100,000.

To achieve these targets, site-wide closure objectives were translated to area-specific closure objectives (as stated in Section 5.1) that were refined into closure criteria that specifically address the following:

- Physical aspects
  - Design service life

  - Design floods
  - Seismic considerations
  - Minimum factors of safety
  - Perpetual disruptive forces

- Chemical aspects
  - Human health
  - Aquatic life
  - Terrestrial habitat

- Radiological aspects

These closure criteria will become closure plan design parameters for the selected remediation alternative, as described in the *Deloro Mine Rehabilitation Project - Development of Closure Criteria, Final Report* (CG&S, October 1998a).

4.4.1 Screening of Conceptual Remediation Methods

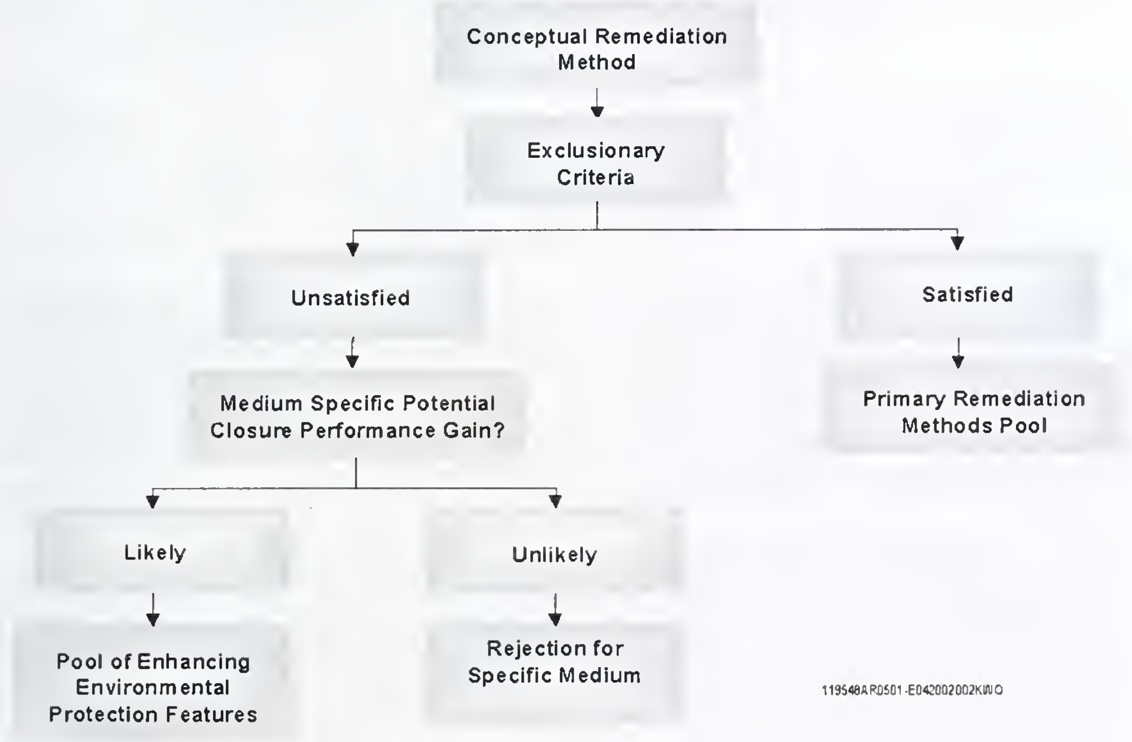
Each conceptual remediation method was consequently evaluated to determine whether it could (yes) or could not (no) meet the exclusionary criteria presented above. A "no" to any of these criteria eliminated the conceptual remediation method as a primary remediation method. A primary remediation method is defined as a method that had significant potential to address most of the environmental issues in this area of the site without further augmentation or enhancement. All criteria carried equal weight in the evaluation process; therefore, their order of appearance does not reflect their relative importance. Table 4.1 further synthesizes the intent of the exclusionary criteria used to generate remediation alternatives.

TABLE 4.1
EXCLUSIONARY CRITERIA – SCREENING OF CONCEPTUAL REMEDIATION METHODS

Exclusionary Criteria	Considerations	Measure
Effectiveness	Does the conceptual remediation method have the potential to solve one or more aspects of the problem? (I.e. Can it contribute to a significant attenuation of any unacceptable impacts on human health or the environment by way of reducing a component of the contaminant load?)	Yes – The conceptual remediation method has the potential to significantly reduce contaminant loads to the environment. No – The conceptual remediation method does not have the potential to significantly reduce contaminant loads to the environment.
Government Regulations and Guidelines	Does the conceptual remediation method conform in principle to applicable government regulations and guidelines relating to site rehabilitation? (e.g. Guideline for Use at Contaminated Sites, Mining Act and Rehabilitation Guidelines?)	Yes – The conceptual remediation method is more likely to conform. No – The conceptual remediation method is less likely to conform.
Design Closure Criteria	Is the conceptual remediation method likely to satisfy design closure criteria pertaining to site-specific risk assessment of human health and environmental impacts if developed in greater detail?	Yes – The conceptual remediation method has the potential to satisfy design criteria. No – The conceptual remediation method has no potential to satisfy design criteria.

Rejection as a primary remediation method did not exclude further consideration of the method to augment another conceptual remediation method, particularly if the former showed significant potential to control the release or minimize the mobility of contaminants in a specific medium (groundwater, surface water, soil or air). Some methods were retained based on their potential for combination with other methods to create a comprehensive solution to the environmental issues in an area. Such combinations were termed "Comprehensive Remediation Alternatives". Other methods were retained as potential enhancements, which formed redundancies in the design, such as multiple barriers to contaminant release/migration. Figure 4-1 illustrates the process used to screen conceptual remediation methods.

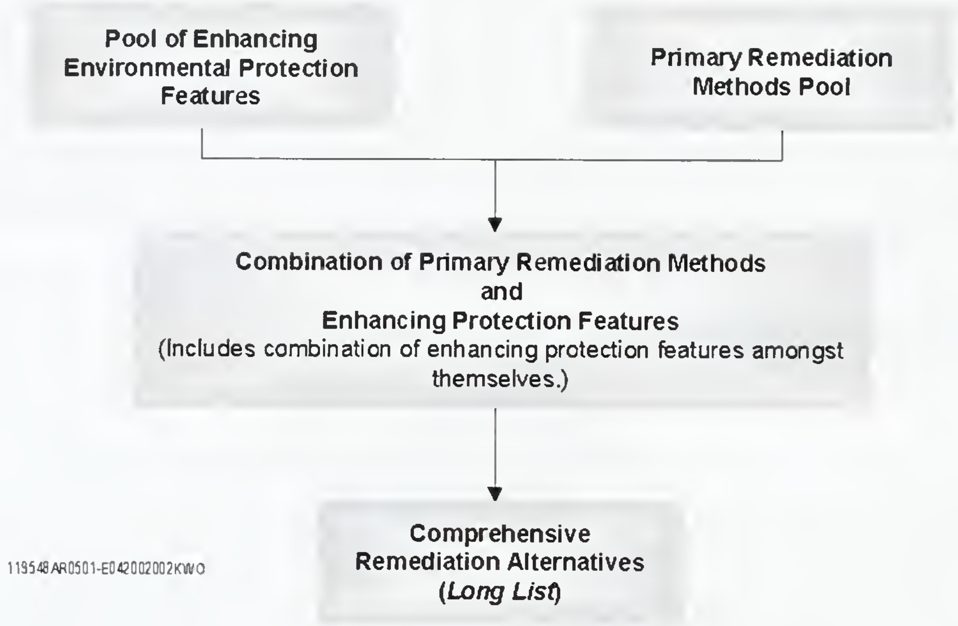
FIGURE 4-1
SCREENING OF CONCEPTUAL REMEDIATION METHODS – SCHEMATIC DIAGRAM



4.4.2 Development of Comprehensive Remediation Alternatives

Figure 4-2 schematically illustrates the process used to generate comprehensive remediation alternatives for further consideration. Alternatives were developed from the list of primary remediation methods that have passed the screening level evaluation. Comprehensive remediation alternatives were developed to create potential solutions that addressed all of the environmental issues or problems in each area. Where primary remediation methods have been identified through the screening process, the team considered how the method could be augmented or enhanced to address all the issues. In developing comprehensive remediation alternatives, the project team considered the multiple goals and objectives that must be achieved for an acceptable solution. In particular, comprehensive remediation alternatives were developed to mitigate the release of contaminants to the environment along various exposure or migration pathways.

FIGURE 4-2
DEVELOPMENT OF COMPREHENSIVE REMEDIATION ALTERNATIVES – SCHEMATIC DIAGRAM



In addition to developing comprehensive remediation alternatives that just meet the project requirements, our team has also considered augmenting or enhancing these alternatives to provide greater certainty through additional levels of protection. These enhancing environmental protection features were considered as design redundancies or contingencies that provide multiple barriers to contaminant release/migration and serve to increase the level of confidence that an alternative will achieve the project goals.

4.5 Evaluation of Comprehensive Remediation Alternatives

The evaluation process that was developed to select a recommended remediation alternative for the area of the site relied on a qualitative assessment of the comprehensive remediation alternatives. It allowed the evaluation to focus on the alternatives that are most promising to satisfy the closure objectives while avoiding consideration of superfluous alternatives.

Comprehensive remediation alternatives were evaluated using the process illustrated in Figure 4-3. The first step in selecting a recommended remediation alternative was to compare all comprehensive remediation alternatives (the "long list") to a second set of exclusionary criteria identified in Table 4.2 as a screening exercise. This step ensured that the combination of an environmental protection feature with a primary remediation method did not undermine the potential effectiveness of the latter. The exercise led to the construction of a "short list" of comprehensive remediation alternatives from which the recommended remediation alternative was selected. It is important to recognize that while the first set of exclusionary criteria shown in Table 4.1 deals mainly with the evaluation of *methods* which have the potential to form *part* of a comprehensive solution, such as reduction of a component of contaminant load to the environment, the second set of exclusionary criteria shown in Table 4.2 focuses on the screening of *comprehensive solutions* and their ability to achieve an overall reduction of contaminant load from the area.

TABLE 4.2
EXCLUSIONARY CRITERIA – SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Exclusionary Criteria	Considerations	Measure
Effectiveness	Does the comprehensive remediation alternative solve the problem? (i.e. Can it contribute to a significant attenuation of any unacceptable impacts on human health or the environment by way of reducing contaminant loads from the entire Area?)	Yes – The comprehensive remediation alternative has the potential to significantly reduce contaminant loads to the environment. No – The comprehensive remediation alternative does not have the potential to significantly reduce contaminant loads to the environment.
Government Regulations and Guidelines	Does the comprehensive remediation alternative conform to applicable government regulations and guidelines relating to site rehabilitation? (e.g. Guideline for Use at Contaminated Sites, Mining Act and Rehabilitation Guidelines)	Yes – The comprehensive remediation alternative is more likely to conform. No – The comprehensive remediation alternative is less likely to conform.
Design Closure Criteria	Will the comprehensive remediation alternative satisfy design closure criteria pertaining to site specific risk assessment of human health and environmental impacts?	Yes – The comprehensive remediation alternative has the potential to satisfy design criteria. No – The comprehensive remediation alternative has no potential to satisfy design criteria.

The detailed evaluation of the short-listed comprehensive remediation alternatives was completed by comparing them against a series of evaluation criteria that not only reflected the objectives of the project but that also captured the essence of environmental assessment criteria that are commonly applied by the MOE when it is required to evaluate impacts associated with a given project. Appendix A illustrates how the detailed evaluation criteria used in the process described here and the environmental assessment screening criteria are related.

The detailed evaluation criteria consist of four categories of criteria listed below. All criteria carry equal weight in the evaluation process and consequently their order of appearance does not reflect the relative importance of each criterion.

- Technical Considerations
  - Reliability
  - Compatibility with existing system
  - Ease of implementation
- Costs
  - Operation and maintenance costs
  - Capital costs
- Social Considerations
  - Public acceptance
  - Risk to public
  - Constraint for recreational use
  - Negative impact to private properties
  - Visual character of the area
  - Risk to workers

- Natural Environment
  - Geochemistry
  - Terrestrial habitats
  - Floodplain
  - Fish habitats

Table 4.3 summarizes the intent of the detailed evaluation criteria. Further descriptions of each category of criteria are provided below.

TABLE 4.3
DETAILED EVALUATION CRITERIA – COMPREHENSIVE REMEDIATION ALTERNATIVES

Criteria	Considerations	Measure
Technical Considerations		
Reliability	Ability of the alternative to satisfactorily control discharge quality on a regular and reliable basis	Good – Very reliable, few performance problems Fair – Somewhat reliable, some performance problems Poor – Not reliable, many performance problems
Compatibility with Existing System	Ability of the alternative to adapt to the existing site conditions and system	Good – Very compatible, few technical problems Fair – Somewhat compatible, some technical problems Poor – Not compatible, many technical problems
Ease of Implementation	Ability of the alternative to be easily implemented from a technical perspective (e.g. land availability, timing, approval requirements)	Good – Easily implemented, few problems Fair – Somewhat easily implemented, some problems Poor – Not easily implemented many problems encountered
Costs		
Operation & Maintenance Costs	Relative measure of O&M costs compared to other alternatives	High – Relatively high operating and maintenance costs Moderate – Relatively moderate operating and maintenance costs Low – Relatively low operating and maintenance costs
Capital Costs	Relative measure of capital costs compared to other alternatives	High – Relatively high capital costs Moderate – Relatively moderate capital costs Low – Relatively low capital costs
Social Considerations		
Public Acceptance	The potential for the comprehensive remediation alternative to be accepted by the public	High – Minimal or no potential for some reservation from the public Moderate – Potential for some reservation from the public Low – Potential for significant reservation from the public
Risk to Public	The potential for the comprehensive remediation alternative to create a risk to public safety	High – Potential for significant risk to public safety Moderate – Potential for some risk to public safety Low – Potential for low/no risk to public safety

TABLE 4.3
DETAILED EVALUATION CRITERIA – COMPREHENSIVE REMEDIATION ALTERNATIVES

Criteria	Considerations	Measure
Constraint for Recreational Use	The potential for the comprehensive remediation alternative to create constraints for recreational opportunities	High – Potential for significant constraints on recreational opportunity Moderate – Potential for some constraints on recreational opportunity Low – Minimal or no constraints for recreational opportunity
Negative Impact to Private Properties	The potential for the comprehensive remediation alternative to produce a negative impact to private properties	High – potential for significant negative impact to surrounding private properties Moderate - potential for some negative impacts on surrounding private properties Low – minimal or no negative impacts on surrounding private properties
Visual Character of the Area	The potential for the comprehensive remediation alternative to impact the visual character of the area	High – Potential to severely impact the visual character of an area Moderate – Potential to have some impacts on the visual character of an area Low – Minimal impacts on the visual character of an area
Risk to Workers	The potential for the comprehensive remediation alternative to create a risk to workers	High – Potential for significant risk to workers Moderate – Potential for some risk to workers Low – Potential for low/no risk to workers
Natural Environment		
Geochemistry	The potential for the alternative to improve the geochemistry of the area	High – High potential to improve the geochemistry Moderate – Some potential to improve the geochemistry Low – Low potential to improve the geochemistry
Terrestrial Habitats	The potential of an alternative to improve terrestrial habitats	Good – Potential to significantly improve terrestrial habitats Fair – Potential to somewhat improve terrestrial habitats Poor – Minimal or no improvement to terrestrial habitats
Floodplain	The potential of the alternative to disrupt/intrude upon the floodplain	High – Potential to disrupt/intrude upon floodplain resulting in potentially significant impacts to the system. Moderate – Potential to cause some disturbance or intrusion into floodplain; impacts less severe Low – Minimal/no disturbance; alternative offers the opportunity to "cleanup" floodplain.
Fish Habitats	The potential of the alternative to cause disturbance to or loss of fisheries habitat	High – Potential to cause disturbance or loss of significant area of fisheries habitat, significant compensation measures required; Moderate – Potential to cause some disturbance or loss of fisheries habitat, some mitigation required; Low – Minimal disturbance or no loss of fisheries habitat

4.5.1 Technical Considerations

The first technical criterion dealt with the comprehensive remediation alternative's technical reliability in mitigating human health and environmental impacts from the area. Surface

water runoff and/or groundwater discharge have been identified as the main loading sources for the influx of arsenic and metals to the Moira River and Young's Creek. The ability to reduce the contact between the groundwater and the wastes or redirect the groundwater cross flow along with other water inputs to the area also form the basis for the evaluation of the comprehensive remediation alternative's reliability. The ability of the alternative to satisfactorily control discharge on a regular and reliable basis over the long term was considered paramount. These discharges and water inputs can be reduced by selecting or combining some of the following design principles:

- Reducing the amount of precipitation that infiltrates into the impacted materials
- Reducing the amount of groundwater contacting the impacted materials
- Lowering the static groundwater table below the lower horizon of impacted materials
- Intercepting surface water runoff and divert the flow away from the impacted materials
- Minimizing the onsite retention time of any uncontaminated water
- Reducing the contact area of the impacted materials
- Placing the wastes above the water table
- Reducing the rate at which water moves through the wastes

The second criterion examined the comprehensive remediation alternative's ability to operate in tandem with existing systems operating at the site, if present, notably the existing groundwater pumping and arsenic treatment system in the Industrial Area.

Finally, the ease to construct and implement the comprehensive remediation alternative was examined as a precursor to following criteria. Issues such as sufficient workspace, available technologies and complexity were addressed.

4.5.2 Costs

The second category of criteria used for the evaluation of rehabilitation alternatives was costs. Capital, construction, and operation and maintenance costs (O&M) for the comprehensive remediation alternatives were considered relative to each other. Costs were based upon the engineering complexity and work required to implement the alternative.

Costs were estimated on the basis of conceptual remediation plans derived from the conceptual remediation alternatives identified earlier in this process. Budgetary estimates were calculated for this evaluation process and meant to provide an indication of the magnitude of the cost associated with each comprehensive remediation for comparison purposes only. The cost estimates are presented in 2002 dollars.

4.5.3 Social Considerations

Criteria in this category addressed the ability of the remediation alternatives to meet social needs and expectations such as future recreational use of the property, impacts of the works on private property and the overall visual character of the site.

An important step in evaluating the alternatives was the ability to mitigate the threat to human health. The risk to human health was considered for the general public, rehabilitation staff and workers involved in ongoing operation and maintenance of the site, based on the potential for acute and long-term effects.

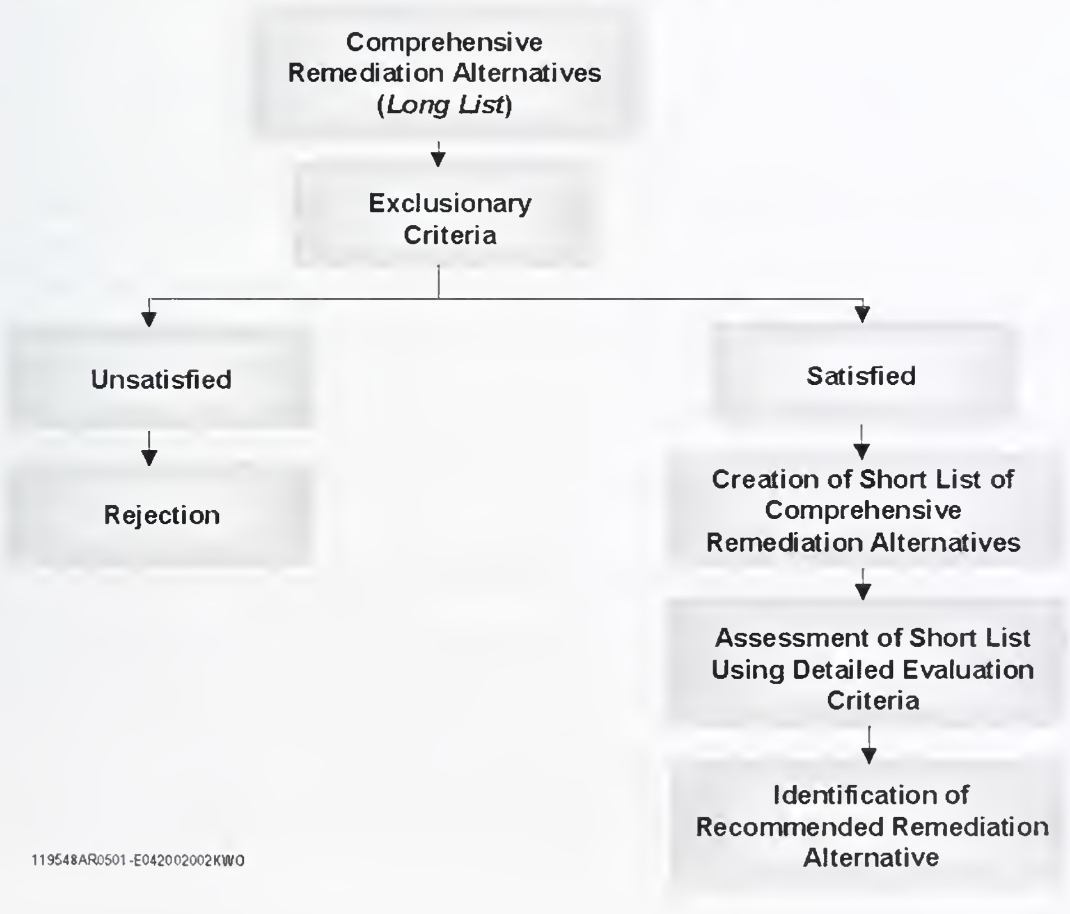
4.5.4 Natural Environment

This category encompasses all of the natural environmental components not covered in the above subsection. This evaluation examined the alternative's ability to improve or protect the following:

- Geochemistry (Surface water and groundwater quality)
- Terrestrial habitats
- Floodplains
- Fish habitats

Figure 4-3 schematically illustrates the process used for the detailed evaluation of the short-listed comprehensive remediation alternatives to determine the recommended remediation alternative.

FIGURE 4-3
EVALUATION OF COMPREHENSIVE REMEDIATION ALTERNATIVES – SCHEMATIC DIAGRAM



4.6 Summary

The strategic direction of the Deloro Mine Site Cleanup Project in the early 1990s was to manage wastes onsite. Based on the overall project objective, which is to mitigate any unacceptable impacts on human health and the environment, a process was developed to

generate "reasonable" comprehensive remediation alternatives for the area. The system relied on the use of exclusionary criteria to identify conceptual remediation alternatives that may be applicable for the area. It also allowed for the development of enhancing environmental protection features that could augment the level of protection offered by any given remediation alternative.

Following the generation of a long list of comprehensive remediation alternatives, each alternative was evaluated against two sets of criteria to identify a recommended remediation alternative. This evaluation of the alternatives against the first set of criteria resulted in a short list of comprehensive remediation alternatives that was evaluated in greater detail using the second set of criteria (i.e. the detailed evaluation criteria). The latter criteria provided a more detailed level of comparison of each alternative with respect to the others and allowed the selection of a recommended remediation alternative for the area.

An alternative was recommended that satisfied the greatest number of criteria and provided the greatest value to MOE based on the professional judgement of the CH2M HILL team.

5. Development and Evaluation of Alternatives

The development and evaluation of remediation alternatives for the Industrial Area is driven by the closure objectives discussed in the following section.

5.1 Remedial and Closure Objectives

The following closure objectives developed for the Industrial Area reflect the overall remedial objectives for the Deloro site, as stated in Section 4.2:

1. Develop a rehabilitation closure plan supported by a Site Specific Risk Assessment (SSRA)
2. Develop/implement risk reduction plans according to site-wide priorities
3. Removal of wastes and residues from the area impacted by the design flood event
4. Provide flood protection for wastes/residues outside the design flood event
5. Manage radioactive materials to reduce radiation at ground surface to background levels
6. Cover and grade wastes/residues with material suitable to minimize infiltration
7. Isolate wastes/residues to eliminate, to the extent possible, releases to the environment according to the site-wide priorities
8. Co-manage wastes of similar risk (i.e. consolidate higher risk wastes and provide a suitably high degree of containment)
9. Design life for engineered facilities consistent with accepted design practice

5.2 Identification of Conceptual Remediation Methods

Extensive evaluation of remediation alternatives for the Industrial Area has been completed by J.L. Richards & Associates Ltd. (Richards, 1990). The current work by CH2M HILL is intended to confirm and refine rather than duplicate this previous evaluation.

As described in Section 4.3, the first step in the generation of remediation alternatives for the Industrial Area consisted in identifying conceptual remediation methods that have been applied in similar situations. The conceptual remediation methods that were identified for the Industrial Area are:

- Do nothing
- Recycling/mineral recovery
- Enhanced groundwater collection
- Stabilization/solidification
- Consolidate and cover
- Cap/cover in place

- Divert groundwater/surface water flow
- Full encapsulation
- Full encapsulation and contaminant leaching

Each of these conceptual remediation methods is described in general terms below:

5.2.1 Do Nothing

This method consists of not modifying current site conditions in any way and as such, it does not constitute a "genuine" conceptual remediation method. However, the "do nothing" scenario is typically considered in evaluation schemes such as this one because it helps determine current site conditions in terms of contaminant release pathways, exposure routes and contaminant loading. It constitutes a baseline against which other conceptual methods can be compared.

5.2.2 Recycling/Mineral Recovery

The basic concept of this method is to attempt to recover minerals/metals of potential economic value (i.e. arsenic, cobalt, copper, nickel, and silver) from the mining and refining wastes located in the Industrial Area. The intent of the method is to decrease the volume of waste that currently exists at the site (by removing the valuable fraction) and to generate funds through the sale of recovered minerals/metals. These funds could then be applied to the cleanup effort. This conceptual remediation method requires the installation and operation, onsite, of a mobile processing plant.

5.2.3 Enhanced Groundwater Collection

The principle of this conceptual remediation method is to augment the surface area over which groundwater is currently being extracted, specifically from the downgradient (i.e. eastern) section of the Industrial Area. This method involves the construction of additional overburden and bedrock pumping wells to intercept a greater proportion of the arsenic impacted groundwater that currently migrates to the Moira River. In this scenario, collected groundwater is piped to the equalization storage basin.

5.2.4 Stabilization/Solidification

This conceptual remediation method involves the addition of a binding agent into the wastes. The function of the binding agent is to immobilize the waste, minimize its hydraulic conductivity (by filling in the pore space) and ultimately its leachability. A typical binding agent is a combination of Portland cement and various additives. Research is currently being conducted with other types of binding agents such as bitumen.

The approximate potential volume of waste that would be subjected to this remediation alternative is 13,800 m^3 as follows:

- 6,200 m^3 of calcium arsenite currently exposed in the central section of the Industrial Area (Witteck, 1986)
- 2,400 m^3 of calcium arsenite based on limited observations by others of white powdery material in borehole GA 12 (Golder, 1988)
- Up to 5,200 m^3 of fill overlying the 2,400 m^3 of material described above (Golder, 1988)

Stabilization/solidification processes can be adapted to suit site-specific conditions either in-situ or ex-situ. Several sub-methods are succinctly described below:

- **In-Situ Stabilization/Solidification.** The in-situ process consists of mixing the wastes, while they are in place, with a slurry of Portland cement using either powerful, large diameter (order of a few meters) augers or other excavation equipment.
- **Ex-Situ Stabilization/Solidification.** The ex-situ process requires excavation of the wastes, mixing of the wastes with a cement slurry in a rotary mixer and pouring of the mixture into forms to create blocks of solidified wastes. The blocks are subsequently buried in a containment cell onsite or offsite.
- **Ex-Situ Offsite Stabilization/Solidification.** A variation of the ex-situ process described above involves the excavation of the wastes and their offsite solidification and disposal at a licensed site.

5.2.5 Consolidate and Cover

Another conceptual remediation method that was considered is the excavation and consolidation of the most impacted materials of the Industrial Area in one portion of the site with the construction of an engineered cover over that portion of the site. The goals of this method are to minimize:

- Contact between surface water runoff and the wastes
- Infiltration of precipitation into the wastes
- Subsequent contaminant leaching and migration to the Moira River
- Offsite migration of contaminants by wind transport

In this case, the footprint of the wastes is reduced significantly, which further minimizes the potential for contact between surface water, infiltrated water and the wastes. This, in turn, further reduces the potential for contaminant load transfer to the environment. The less impacted portions of the Industrial Area would be covered with a simple clay cap. Under this method, the use of heavy earth moving equipment is required at the site, not only to construct the cap and engineered cover but, first and foremost, to excavate and consolidate the wastes. It is anticipated that special health and safety measures will have to be implemented to ensure the protection of onsite workers and the general public during operations involving handling of the wastes.

5.2.6 Cap/Cover in Place

This conceptual remediation method involves the installation of simple clay caps over the less impacted portions of the site and the construction of engineered covers over the most impacted areas of the Industrial Area. Both clay caps and engineered covers would ultimately be vegetated. The goal of this method is the same as the 'consolidate and cover' option in terms of minimizing contaminant load to the environment. However, the remediation can be completed with minimal waste handling. This method requires the use of heavy earth moving equipment on the site.

5.2.7 Divert Groundwater/Surface Water Flow

This conceptual remediation method involves intercepting unimpacted groundwater and surface waters entering the Industrial Area through the western and northern site

boundaries prior to contact with the buried wastes, thereby preventing contamination of unimpacted waters. It also serves to lower the watertable below the base of the wastes, minimizing migration of dissolved contaminants to the Moira River.

In this method, water interception is accomplished through the construction of a large diameter subsurface drain and surface ditch that will be designed to divert "clean" ground and surface water to an existing surface water body (e.g. New Westerly Creek). Construction of such a drain involves the use of heavy machinery and bedrock blasting but relatively little handling of buried wastes.

5.2.8 Full Encapsulation

This conceptual remediation method requires the construction of a state-of-the-art waste containment cell in the Industrial Area. The method calls for the excavation of all wastes, construction of a composite engineered bottom liner, the placement of the excavated wastes into the cell and the construction of a composite engineered cap to permanently seal the waste cell. This method requires extensive handling of the wastes using heavy equipment and the development of temporary storage areas.

5.2.9 Full Encapsulation and Contaminant Leaching

This method is a variation of the one described above and is inspired by household landfill sites, where leachate is re-circulated through the wastes to decrease the potential contaminating life span of the landfill sites. As in the previous method, this method calls for the excavation and the temporary storage of the existing wastes and the construction of an engineered composite waste cell. However, the main distinction of this method is that water is actually introduced into the cell and allowed to percolate through the wastes to promote leaching of the contaminants. The leachate that accumulates on the bottom of the cell would be pumped to the wastewater treatment plant to remove dissolved phase contaminants (e.g. arsenic). The method requires extensive handling of the wastes using heavy equipment and the development of temporary storage areas. It also requires the installation of water percolation and pumping equipment. As a function of the nature and concentration of the contaminants present in the leachate, modifications may have to be implemented at the existing wastewater treatment plant to ensure that all contaminants are effectively removed from the leachate prior to effluent discharge to the Moira River.

5.3 Screening of Conceptual Remediation Methods

The second step used in the generation of remediation alternatives was to compare the conceptual remediation methods described above to the set of exclusionary criteria identified in Table 4.1. As explained in Section 4.3, these criteria were designed to eliminate, early in the process, improbable conceptual remediation methods for the area under consideration. From the nine conceptual remediation methods listed above, only three satisfied the exclusionary criteria and were retained as primary remediation methods. Table 5.1 details the rationale used to exclude the six conceptual remediation methods that were rejected as primary remediation methods.

TABLE 5.1
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria			Selected as a Primary Remediation Method?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria		
Do Nothing	No – Does not have the potential to significantly reduce contaminant loads to the environment	No – Doing nothing would not conform to applicable government regulations and guidelines	No – The conceptual remediation method has no potential to satisfy design closure criteria as main contaminant release pathways will remain unattenuated	No	No
Recycling/mineral recovery	No – Does not have the potential to significantly reduce contaminant loads to the environment as the market for arsenic (the main contaminant in the Industrial Area) is non-existent. Refined arsenic (whatever form) would still have to be "disposed of" onsite.	Yes – Recycling/recovering minerals/metals is likely to conform to government regulations and guidelines.	Yes – The conceptual remediation method has the potential to satisfy design criteria	No	No
Enhanced groundwater collection	Yes – Does have the potential to significantly reduce contaminant loads to the environment	No – Enhanced groundwater collection only is less likely to conform to applicable government regulations and guidelines	No – The conceptual remediation method has no potential to satisfy design closure criteria as main contaminant release pathways will remain unattenuated	No	Yes
Stabilization/ solidification	Yes – Does have the potential to significantly reduce contaminant loads to the environment as potential for contaminant leaching is greatly reduced	Yes – Stabilizing/solidifying leachable wastes is likely to conform to government regulations and guidelines	No – The conceptual remediation method has no potential to satisfy design closure criteria (on its own) as it can only applied to one waste type (calcium arsenite)	No	Yes
Consolidate and cover	Yes – Does have the potential to significantly reduce contaminant loads to the environment as potential for contaminant leaching is greatly reduced	Yes – Consolidating and covering wastes in place is likely to conform to government regulations and guidelines	Yes – The conceptual remediation method has the potential to satisfy design criteria	Yes	No

TABLE 5.1
SCREENING OF CONCEPTUAL REMEDIATION METHODS

Conceptual Remediation Method	Exclusionary Criteria: Effectiveness	Exclusionary Criteria: Government Regulations and Guidelines	Exclusionary Criteria: Design Closure Criteria	Selected as a Primary Remediation Method?	Selected as Enhancing Environmental Protection Feature or Component of Primary?
Cap/cover in place	Yes – Does have the potential to significantly reduce contaminant loads to the environment as potential for contaminant leaching is greatly reduced	Yes – Capping/covering wastes in place is likely to conform to government regulations and guidelines	Yes – The conceptual remediation method has the potential to satisfy design criteria	Yes	No
Divert groundwater/ surface water flow	Yes – Does have the potential to significantly reduce contaminant loads to the environment as potential for contaminant leaching is reduced	Yes – Diverting groundwater/ surface water flow is likely to conform to government regulations and guidelines	No – The conceptual remediation method has no potential to satisfy design closure criteria as main contaminant release pathways will remain unattenuated	No	Yes
Full encapsulation	Yes – Does have the potential to significantly reduce contaminant loads to the environment as potential for contaminant leaching is reduced	Yes – Encapsulating the wastes in an engineered waste cell is likely to conform to government regulations and guidelines	Yes – The conceptual remediation method has the potential to satisfy design criteria	Yes	No
Full encapsulation and contaminant leaching	Yes – Does have the potential to significantly reduce contaminant loads to the environment	No – Full encapsulation and contaminant leaching is less likely to conform to applicable government regulations and guidelines	Yes – The conceptual remediation method has the potential to satisfy design criteria	No	No

Primary remediation methods retained for the Industrial Area are:

- Consolidate and cover
- Cap/cover in place
- Full encapsulation

Among the six conceptual remediation methods that were rejected as primary remediation methods, three were judged to be adequate as enhancing environmental protection features. They are as follows:

- Enhanced groundwater collection
- Stabilization/solidification (selective)
- Divert groundwater/surface water flow

5.4 Development of Comprehensive Remediation Alternatives

The last step in generating the remediation alternatives consisted of combining the primary remediation methods and adding enhancing environmental protection features identified above.

In total, 16 comprehensive remediation alternatives were generated. They are as follows:

1. Consolidate and cover
   a) Consolidate and cover with ground and surface water flow diversion
   b) Consolidate and cover with ground and surface water flow diversion and selected solidification
   c) Consolidate and cover with ground and surface water flow diversion and selected offsite disposal
   d) Consolidate and cover with ground and surface water flow diversion and enhanced groundwater collection
   e) Consolidate and cover with ground and surface water flow diversion, selected solidification and enhanced groundwater collection
   f) Consolidate and cover with ground and surface water flow diversion, selected offsite disposal and enhanced groundwater collection
2. Cap/cover in place
   a) with options a) through f) as above
3. Full encapsulation
   a) Full encapsulation and enhanced groundwater collection

5.5 Screening of Comprehensive Remediation Alternatives

Because all comprehensive remediation alternatives resulted from a combination of primary remediation methods and/or enhancing environmental protection features, they were evaluated against the second set of exclusionary criteria (see Table 4.2) for remediating the entire Industrial Area to ensure that the addition of protection features to the primary remediation methods did not violate the criteria. A summary of whether the comprehensive

remediation alternatives did or did not satisfy these criteria is presented in Table 5.2. In the case of the Industrial Area, the 16 comprehensive remediation alternatives satisfied the exclusionary criteria and constitute the short list of remediation alternatives that was evaluated in detail.

5.5.1 Description of Short-Listed Alternatives

A detailed description of the comprehensive remediation alternatives that satisfied the exclusionary criteria is provided below. Each description includes a discussion of the following points:

- Expected performance relative to dissolved contaminant loading and the interim Provincial Water Quality Objectives (PWQO) in Young's Creek and the Moira River at the intersection of these water courses and Highway 7
- Levels of redundancy offered by the comprehensive remediation alternative

Consolidate and Cover Wastes

This comprehensive remediation alternative consists of the reduction of the footprint of the existing waste containing area. The latter is approximately 150,000 m^2. Through excavation and consolidation of approximately 220,000 m^3 of various types of wastes, the footprint of the wastes will be reduced to an area of approximately 70,000 m^2, which significantly reduces the leachate generating potential of the waste. Under this scenario, wastes will be consolidated in the central portion of the Industrial Area and protected by an engineered cover. Remaining areas of the site will be covered by a simple earth or clay cap.

An engineered cover is essentially a low hydraulic conductivity barrier designed to minimize the infiltration of rainwater into the wastes and thereby reduce the contaminant loading of groundwater discharging to the Moira River via groundwater. Experience has shown that a variety of capping designs will achieve a significant reduction in infiltration. Some designs have distinct cost advantages while others offer advantages in stormwater control, long-term reliability or design flexibility. Cover selection factors include the desired balance between capital and construction costs and long-term operation and maintenance costs of the cover. Other factors include: existing topography, stormwater control, area grading, and logistical issues, such as access for equipment and materials.

There exist several different cover construction alternatives depending on:

- Cover thickness
- Texture and moisture of clay
- Soil moisture storage of cap materials
- Type of geosynthetic membrane (e.g. HDPE, LDPE, VLDPE, bentonite impregnated geotextile, etc.)
- Use of a drainage blanket
- Degree of compaction
- Final vegetation type

TABLE 5.2
SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Comprehensive Remediation Alternative	Exclusionary Criteria			Selected?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria	
1. Consolidate and cover wastes	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes infiltration and subsequent vertical water movement through the wastes	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
1a. Consolidate and cover wastes – Groundwater/ surface water flow diversion	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
1b. Consolidate and cover wastes – Groundwater/ surface water flow diversion and selected solidification	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides an additional level of protection via the solidification of the most leachable wastes.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
1c. Consolidate and cover wastes – Groundwater/ surface water flow diversion and selected offsite disposal	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides an additional level of protection via the offsite disposal of the most leachable wastes.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
1d. Consolidate and cover wastes – Groundwater/ surface water flow diversion and enhanced groundwater collection	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides an additional level of protection through enhanced groundwater flow collection that can reduce current arsenic loading rates to the Moira River.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes

TABLE 5.2
SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Comprehensive Remediation Alternative	Exclusionary Criteria			Selected?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria	
1e. Consolidate and cover wastes – Groundwater/ surface water flow diversion, selected solidification and enhanced groundwater collection	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides two additional levels of protection via the solidification of the most leachable wastes and enhanced groundwater flow collection that can reduce current arsenic loading rates to the Moira River.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
1f. Consolidate and cover wastes – Groundwater/ surface water flow diversion, selected offsite disposal and enhanced groundwater collection	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides two additional levels of protection via the offsite disposal of the most leachable wastes and enhanced groundwater flow collection that can reduce current arsenic loading rates to the Moira River.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
2. Cap/cover in place	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes infiltration and subsequent vertical water movement through the wastes	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
2a. Cap/cover in place – Groundwater/surface water flow diversion	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes

TABLE 5.2
SCREENING OF COMPREHENSIVE REMEDIATION ALTERNATIVES

Comprehensive Remediation Alternative	Exclusionary Criteria			Selected?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria	
2b. Cap/cover in place – Groundwater/surface water flow diversion and selected solidification	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides an additional level of protection via the solidification of the most leachable wastes.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
2c. Cap/cover in place – Groundwater/surface water flow diversion and selected offsite disposal	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides an additional level of protection via the offsite disposal of the most leachable wastes.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
2d. Cap/cover in place – Groundwater/surface water flow diversion and enhanced groundwater collection	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides an additional level of protection through enhanced groundwater flow collection that can reduce current arsenic loading rates to the Moira River.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
2e. Cap/cover in place – Groundwater/surface water flow diversion, selected solidification and enhanced groundwater collection	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides two additional levels of protection via the solidification of the most leachable wastes and enhanced groundwater flow collection that can reduce current arsenic loading rates to the Moira River.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes

Table 5.2
Screening of Comprehensive Remediation Alternatives

Comprehensive Remediation Alternative	Exclusionary Criteria			Selected?
	Effectiveness	Government Regulations and Guidelines	Design Closure Criteria	
2f. Cap/cover in place – Groundwater/surface water flow diversion, selected offsite disposal and enhanced groundwater collection	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it minimizes both groundwater lateral flow and infiltration and subsequent vertical water movement through the wastes. It provides two additional levels of protection via the offsite disposal of the most leachable wastes and enhanced groundwater flow collection that can reduce current arsenic loading rates to the Moira River.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
3. Full encapsulation	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it completely isolates the wastes from surrounding media.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes
3a. Full encapsulation – enhanced groundwater collection	Yes – The alternative can contribute to a significant attenuation of any unacceptable impacts to human health and the environment as it completely isolates the wastes from surrounding media. It provides an additional level of protection through enhanced groundwater flow collection that can reduce current arsenic loading rates to the Moira River.	Yes – The alternative is likely to conform to government regulations and guidelines	Yes – The alternative has the potential to satisfy design criteria	Yes

Materials can also be used in various combinations, such as a clay cover underlain by a geosynthetic membrane or drainage layer. For the Industrial Area, two separate cover sections are proposed:

1. A simple earth cap for areas where wastes have been excavated and consolidated elsewhere
2. An engineered cover including capillary barriers, a geosynthetic membrane, subsurface drainage, and moisture retention layers to be placed over the calcium arsenite and other highly leachable hazardous wastes.

Figure 5-1 shows the approximate areal extent for each of the cap sections. Each of these conceptual cap designs is described below.

5.5.2 Simple Earth Cap

In areas where waste materials will have been excavated and removed, the exposed subsoil or rock will be covered with a minimum 300-mm-thick, low permeability earth cover. Greater thicknesses may be required in areas where radioactive slag has been used for construction fill. The cover fill will be compacted to 95 percent standard Proctor maximum dry density at near-optimum moisture contents. Approximately 300 mm of topsoil or mulch will be put in place as a surface cover in order to support vegetation. The completed cover will be seeded promptly upon completion in order to minimize erosion.

In some areas, as shown in Figure 5-1, the simple earth cap will be constructed over consolidated wastes that are non-leachable.

The purpose of the simple earth cover is to provide a substrate for the re-establishment of vegetation and to cover any erodible subsoils or non-leachable wastes that might otherwise be exposed.

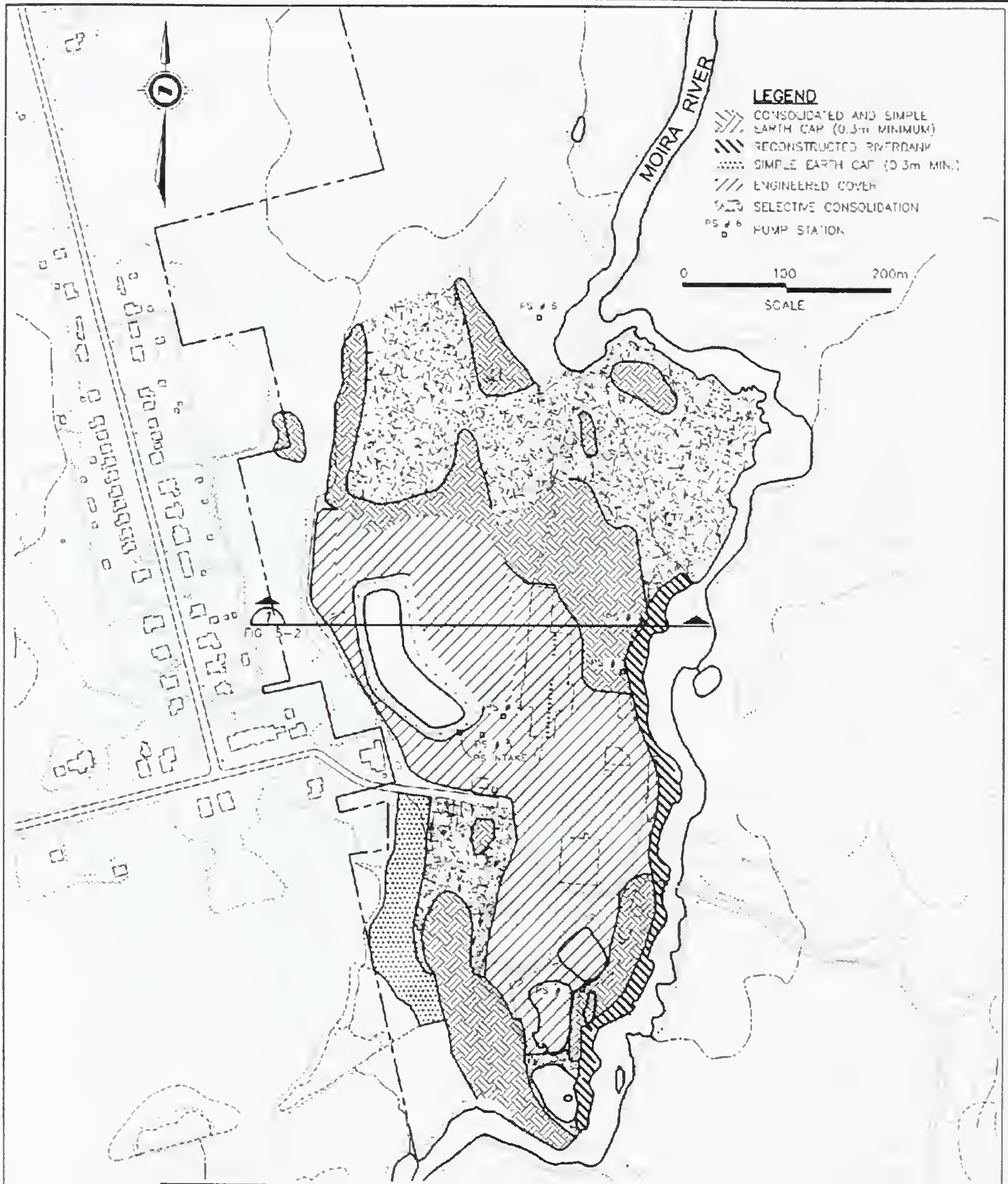
5.5.3 Engineered Cover

The proposed final site layout will include a low permeability earth cover over the leachable waste materials that remain onsite. It has been estimated that infiltration into these wastes must be reduced to less than four percent of precipitation in order to meet surface water quality objectives in the Moira River under scenarios where the collection and treatment system is no longer operated. This level of infiltration reduction is beyond that achievable by a simple compacted clay cover necessitating some form of engineered structure.

There are three means by which infiltration can be reduced to less than four percent:

- Use of a synthetic barrier to infiltration such as a geosynthetic membrane
- Intercepting infiltration through the use of subsurface drainage structures
- Enhancing evapotranspiration and soil moisture storage

Because calcium arsenite is an inorganic contaminant with an indefinite contaminating lifespan, the cover must be designed to maintain its integrity over an extended time period running from centuries to millenia. The integrity of geosynthetic membranes cannot be assured over such lengthy time periods and such membranes should, if used, form a component of the cover structure rather than the primary barrier. Subsurface drainage structures are a desirable component of the cover structure but, like geosynthetic membranes, their long-term performance cannot be guaranteed.



CH2MHILL

PROJECT No. 119548

INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 5-1
SCHEMATIC PLAN VIEW
CONSOLIDATE AND COVER

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The proposed engineered cover consists of a compacted clay and topsoil composite structure incorporating subsurface drainage and vegetation (i.e. poplar trees).

The treed cover concept takes advantage of the tremendous potential water uptake of hydrophyllic tree species such as the locally common poplar and red maple. Data from modelling undertaken by CH2M HILL for the Deloro site indicate that, when planted at an average density of one tree per 3 m^2, poplar have the potential to evapotranspire up to 633.8 mm of water in a growing season running from April to November (CH2M HILL, May 2002). Average annual precipitation in the Deloro area is approximately 900 mm; therefore, theoretically, a treed cover has the potential to evapotranspire most of the annual infiltration. In reality, trees do not reach their potential evapotranspiration because of soil moisture deficit conditions during the dry summer months and some infiltration occurs because precipitation is not evenly distributed throughout the growing season.

In order to minimize infiltration, the cover material must absorb infiltration during the wet spring months and retain this moisture long enough to make it available to the deep rooted vegetation during the peak growing period from May to the end of September. The cover should also have a high runoff coefficient to minimize infiltration during spring runoff and times of heavy precipitation.

The conceptual cover design proposed in this comprehensive remediation alternative for the Industrial Area incorporates moisture retention layers to hold excess infiltration until it can be taken up by evapotranspiration during the summer growing season. From top to bottom the cover components are:

- 300 mm of topsoil or mulch (support for erosion control seeding and ground cover)
- 500 mm of compacted clay (low permeability barrier to minimize infiltration and maximize runoff)
- 250 mm of sand cover
- A bentonite-impregnated geosynthetic membrane
- 500 mm of clay bedding to protect the geosynthetic membrane and serve as a capilliary barrier

The clay component of the cover should have an in-place hydraulic conductivity lower than 1×10^{-6} cm/s (ideally 1×10^{-7} cm/s) and be compactible to a minimum of 95 percent standard Proctor maximum dry density at a near-optimum moisture content. Topsoil components will have an effective volumetric moisture storage capacity (difference of at least 15 percent between field capacity and wilting point) and an in-place hydraulic conductivity of greater than 1×10^{-5} cm/s.

A geosynthetic clay liner (GCL) is included as a secondary infiltration barrier. The liner's non-woven outer geotextile covers provide high strength in tension and against puncture. The inner layer of sodium bentonite swells under contact with moisture to provide a hydraulic barrier. The barrier is effective in resisting stresses from differential settlement.

The completed cover will be vegetated with both poplar trees and grass. The grass cover is intended for short-term erosion control until the tree cover is well established. With maturity, the thick root systems of the poplar trees hold the soil together and the canopy of leaves shields the ground from raindrop impacts and consequent erosion. When the leaves

fall in the autumn, they contribute to the mulch at the site and the overall water-holding capacity of the system. A rougher ground surface develops and water flows more slowly down the slopes. With time, the cover becomes a mature forest with little wind or water erosion (CH2M HILL, May 2002).

Figures 5-1 and 5-2, respectively, show a schematic plan view of the Industrial Area and a typical cross-section through the engineered cover following the implementation of the comprehensive remediation alternative.

Although this comprehensive remediation alternative is expected to significantly reduce contaminant loads to the Moira River, it is doubtful, in the absence of enhancing environmental protection features, that it will satisfy the interim PWQO (MOE, 1994) for dissolved arsenic concentration in the waters of the Moira River at the intersection of Highway 7, south of the Deloro Mine Site.

Consolidation of the wastes will reduce the surface area over which surface water infiltration may contact the wastes, this is expected to result in a significant decrease in the mass of dissolved contaminants that will reach the watertable. Furthermore, the engineered cover and simple earth caps will also reduce surface water infiltration into the wastes, transportation of dissolved contaminants and fine particulates via surface runoff to the Moira River as well as airborne transportation of particulates. One significant contaminant migration pathway that is not addressed by this comprehensive remediation alternative is groundwater flow. It has been established in previous studies that groundwater enters the western site boundary and flows eastward through bedrock, overburden and the wastes to the Moira River. Although a groundwater collection and treatment system is in use at the site (see Section 3.1.1) which reduces the volume of arsenic-impacted groundwater that reaches the Moira River, it is suspected that the system does not capture all arsenic-impacted groundwater.

A more effective way to control groundwater contaminant migration at the site is to actually minimize groundwater contact with the wastes by diverting groundwater flow upgradient of the wastes. Similarly, further reduction of potential infiltration through the engineered cover can be obtained by diverting any surface water run-on from the hills located in the northern portion of the Industrial Area away from the engineered cover. This enhancing feature is described further below.

Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion

This comprehensive remediation alternative is similar to the previous alternative but is enhanced by the construction of a groundwater interceptor trench along the western boundary of the Industrial Area and the construction of a surface water interceptor ditch along the northern boundary of the Industrial Area.

The proposed groundwater interceptor trench will take the form of a ditch excavated through overburden and blasted into bedrock and will intercept groundwater flowing eastward through the western site boundary before it contacts the buried wastes. This will prevent groundwater contamination and subsequent contaminant transport eastward to the Moira River. Intercepted, non-impacted groundwater will be directed southward by gravity to the existing New Westerly Creek, which reaches the Moira River in the southwestern portion of the Deloro Mine Site. The groundwater interceptor trench will also lower the watertable below the base of the wastes, further decreasing the potential for contaminant dissolution in groundwater and migration eastward towards the Moira River.

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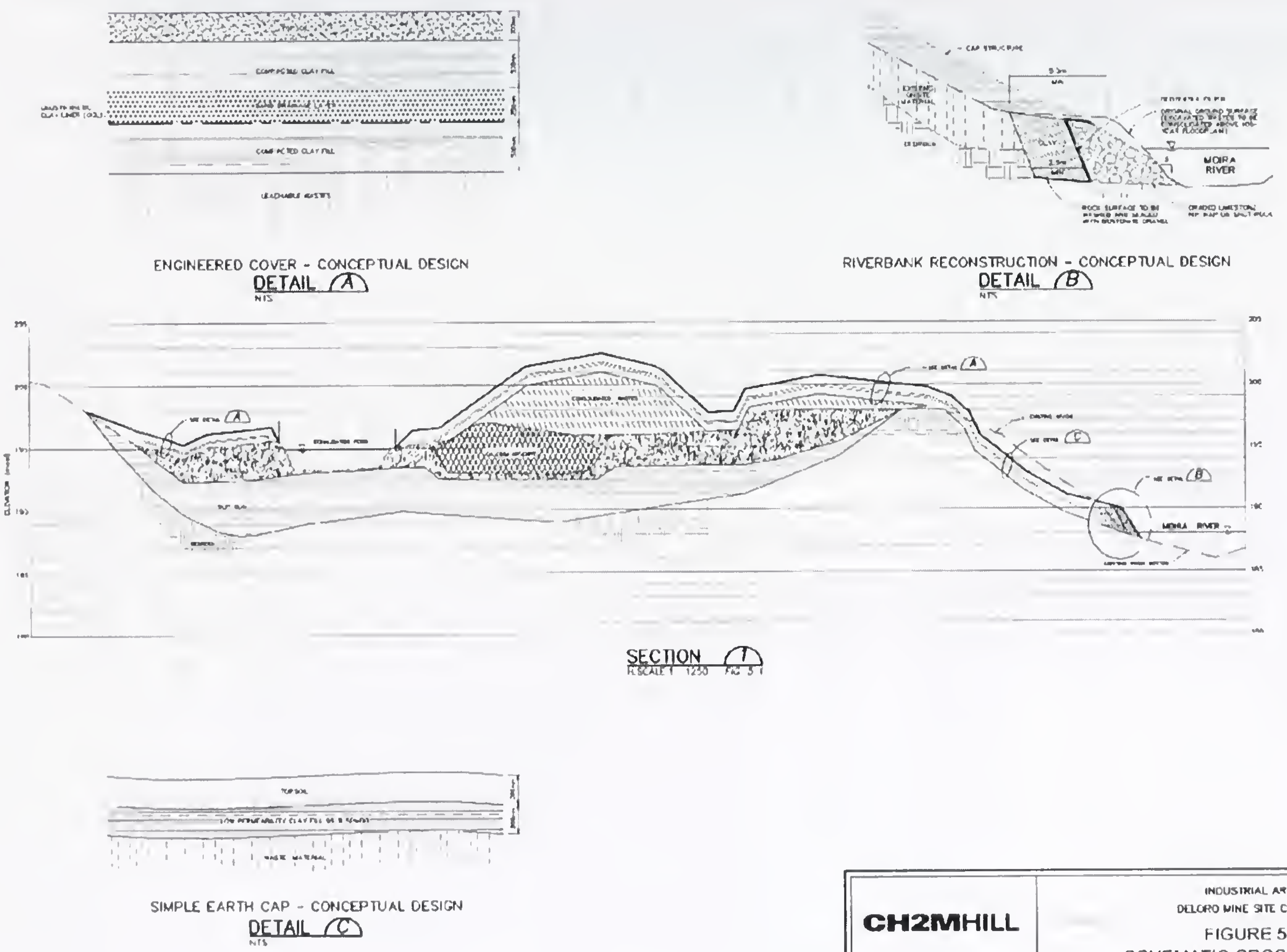

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 5-2
SCHEMATIC CROSS-SECTION
CONSOLIDATE AND COVER

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Similar to the proposed groundwater interceptor trench, it is proposed that a surface water interceptor ditch be constructed at the northern boundary of the Industrial Area to prevent any surface water runoff from the hills located to the north of the waste consolidation area from reaching the engineered cover thereby further minimizing infiltration through the cover. The ditch will trend east-west and is expected to be relatively shallow. It will be excavated through both overburden and bedrock. Intercepted surface water will drain by gravity from the east to the west to the groundwater interceptor trench, which will drain to New Westerly Creek.

Figures 5-3 and 5-4, respectively, illustrate schematic plan and cross-section views of the Industrial Area after waste consolidation and covering/capping and construction of the groundwater flow and surface water runoff diversion structures.

The expected performance of this comprehensive remediation alternative is significantly more effective than the previous alternative. This alternative controls the three main pathways by which contaminants can be released to the environment (i.e. air, surface water and groundwater). Therefore, the implementation of this remediation alternative is likely to satisfy the target interim PWQO for dissolved arsenic concentration at the intersection of the Moira River and Highway 7.

Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion, Selected Stabilization/Solidification

This comprehensive remediation alternative combines the characteristics of the previous one and adds the onsite (ex-situ) stabilization/solidification of the 13,800 m^3 of calcium arsenite and calcium arsenite impacted soil/wastes. In this alternative, not only are wastes going to be consolidated in the central portion of the Industrial Area under an engineered cover, but the most leachable, arsenic rich wastes, will be solidified/stabilized onsite using a mobile treatment system. Assuming that the effective loading of calcium arsenite in the cement matrix is limited, to ensure long term stability of the concrete, at 10 percent (mass of calcium arsenite/mass of concrete and aggregate mix) and that the density of calcium arsenite and cured concrete are approximately equal, the use of the stabilization/solidification technology will effectively increase the volume of treated wastes by a factor of 10. Therefore, the volume of solidified arsenic containing wastes could be as high as 140,000 m^3. In addition to the estimate of approximately 220,000 m^3 of existing various wastes, the use of this technology would increase the volume of onsite wastes to approximately 360,000 m^3.

The expected performance of this alternative in terms of satisfying the interim PWQO for dissolved arsenic concentration at the intersection of the Moira River and Highway 7 is very good. The main source of arsenic will be stabilized and arsenic leachability will be minimized, but the transporting agents (i.e. wind, surface, and groundwater) will be controlled by the construction of the engineered cover and the surface water and groundwater diversion ditch/trench.

Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion, Selected Offsite Disposal

This comprehensive remediation alternative is almost identical to the one described above. However, it includes the offsite disposal of approximately 13,800 m^3 of calcium arsenite and calcium arsenite impacted soil/wastes to a licensed facility. The inclusion of selected offsite disposal is not considered to be a deviation of the strategic direction for the site cleanup as the primary focus for the remediation activities remains onsite management of the wastes. However, because the calcium arsenite waste constitutes the main source of leachable

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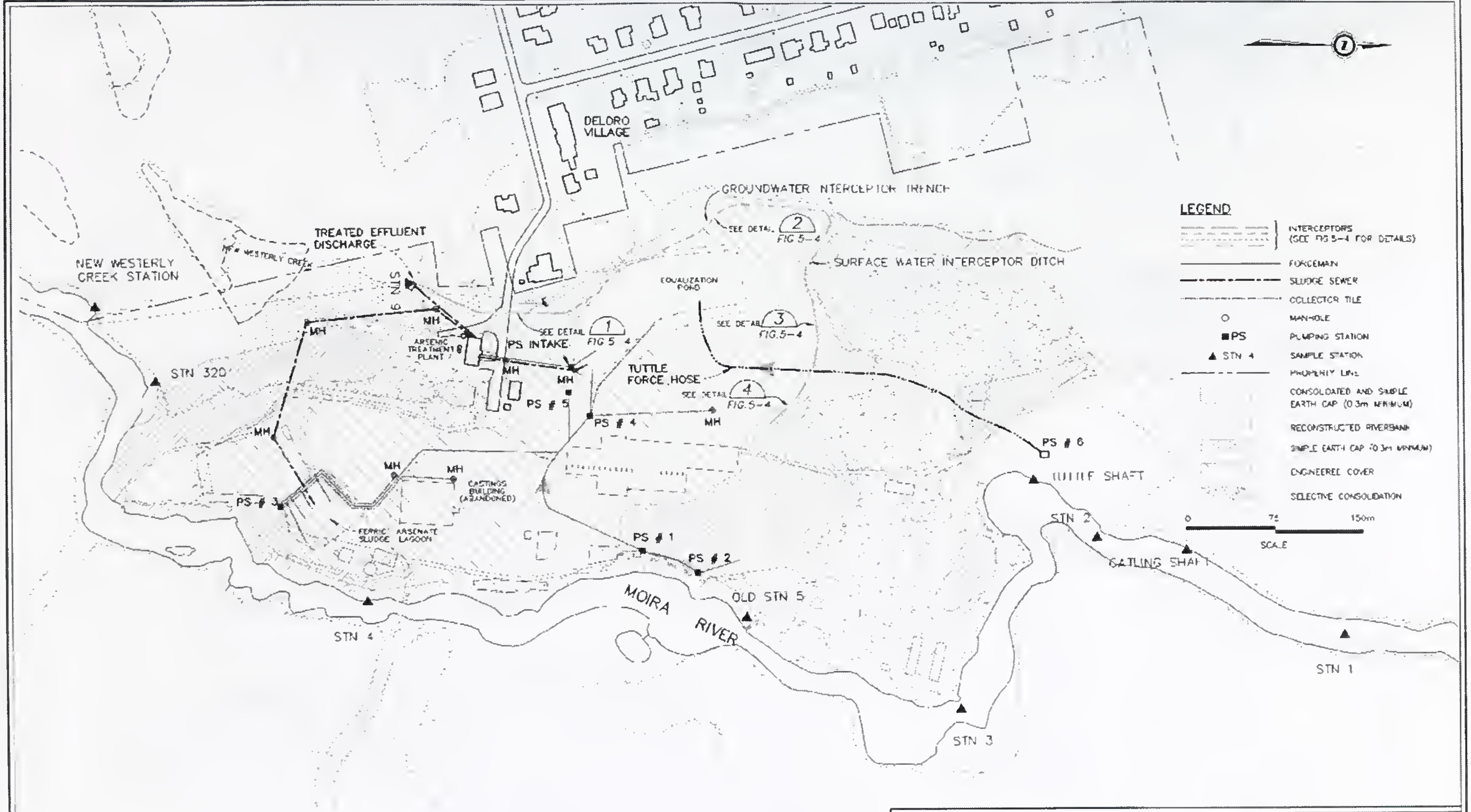

CH2MHILL	INDUSTRIAL AREA DELORO MINE SITE CLEANUP
PROJECT No. 119545	FIGURE 5-3: SCHEMATIC PLAN CONSOLIDATE AND COVER, GROUNDWATER, SURFACE WATER FLOW DIVERSION

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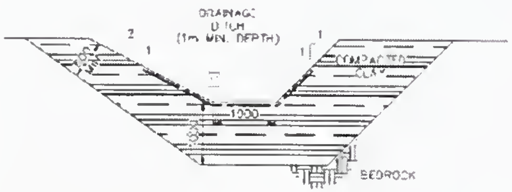
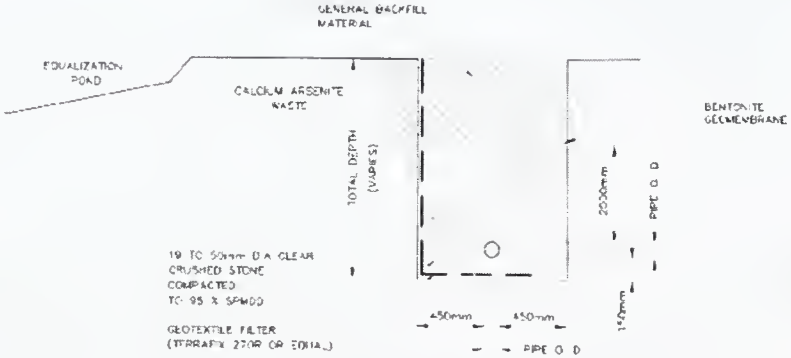
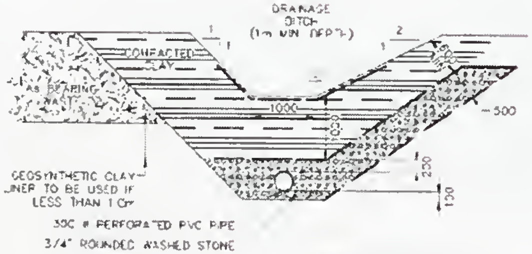


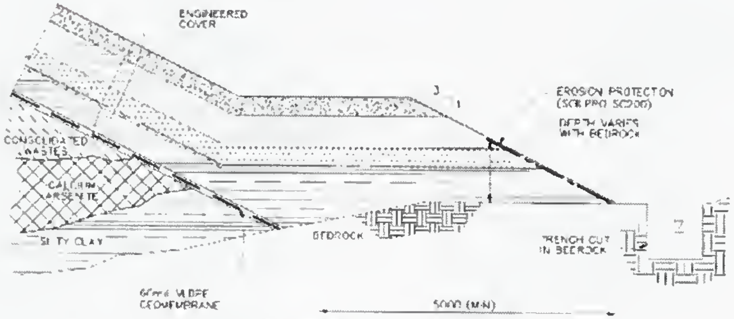
DRAINAGE DITCH – CONCEPTUAL DESIGN
DETAIL 1
NTS FIG.5-3



GROUNDWATER INTERCEPTOR TRENCH – CONCEPTUAL DESIGN
DETAIL 2
NTS FIG.5-3



SURFACE WATER INTERCEPTOR DITCH (OVERBURDEN) – CONCEPTUAL DESIGN
DETAIL 3
NTS FIG.5-3



SURFACE WATER INTERCEPTOR DITCH (BEDROCK) – CONCEPTUAL DESIGN
DETAIL 4
NTS FIG.5-3

DETAIL LEGEND
GEOSYNTHETIC CLAY LINER (BENTOFIX NW)
GEOTEXTILE FILTER (TERRAFIX 270R)
COCONUT FIBRE BLANKET (SCRPRO SC200)

NOTE
ALL DIMENSIONS ARE IN mm
UNLESS NOTED OTHERWISE.

CH2MHILL
PROJECT No. 119548

INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 5-4 : SCHEMATIC CROSS-SECTION CONSOLIDATE AND COVER, GROUNDWATER, AND SURFACE WATER FLOW DIVERSION

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arsenic, its transportation and offsite disposal in a licensed facility effectively removes that main source of arsenic from the site in perpetuity.

Selected offsite disposal of the calcium arsenite and calcium arsenite impacted soil/wastes will require the consolidation of the "white powder" waste observed at surface and in numerous boreholes onto a temporary storage pad where it will be stockpiled and subsequently loaded on licensed trucks. The stockpile must remain covered at all times to prevent particulate transport by wind and leaching by precipitation. This alternative presents some significant health and safety issues for onsite workers and the general public and will require special measures.

The expected performance of this alternative in terms of satisfying the interim PWQO for dissolved arsenic concentration at the intersection of the Moira River and Highway 7 is very good because not only will the source of arsenic have been removed, but the transporting agents (i.e. wind, surface, and groundwater) are controlled by the construction of the engineered cover and the surface water and groundwater diversion ditch/trench.

Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion, Enhanced Groundwater Collection

This comprehensive remediation alternative combines the consolidation of wastes, the construction of an engineered cover over the wastes and simple earth covers over exposed areas, a groundwater interceptor trench and a surface water interceptor ditch. It also incorporates enhanced groundwater collection downgradient (i.e. to the east) of the waste consolidation area.

In this comprehensive remediation alternative, it has been assumed that three additional groundwater withdrawal wells will be installed east of the waste consolidation area to accelerate the catchment of the arsenic groundwater plume that originates from the western portion of the Industrial Area. It is conceived that after the construction of the engineered cover and the diversion of ground and surface water away from the wastes, the watertable will drop in the course of a few years, below the base of the wastes, leaving the wastes at residual water saturation (or "field capacity"). From that point on, the volume of arsenic impacted groundwater that will continue to contribute arsenic to the Moira River will be limited to the groundwater that has moved through the wastes but that has not yet reached the existing groundwater collection system or the Moira River. The construction and operation of three additional pumping wells will enhance recovery of arsenic impacted groundwater by increasing the surface area over which groundwater withdrawal will occur. This will in turn reduce the period of time required to exhaust (or deplete) the arsenic impacted groundwater plume.

The expected performance of this alternative in terms of satisfying the interim PWQO for dissolved arsenic concentration at the intersection of the Moira River and Highway 7 is also very good as the main pathways by which contaminants can be released to the environment are controlled. The engineered cover and simple earth cap will protect the wastes from the elements (e.g. wind and surface water transport of particulates), minimize infiltration of precipitation into the wastes and groundwater lateral flow through the wastes, and the subsequent migration of dissolved contaminants through groundwater. Furthermore, enhanced groundwater collection would further contribute to the reduction of current arsenic loading to the Moira River. Figure 5-5 shows a schematic plan view and cross-section of the Industrial Area following the implementation of this alternative.

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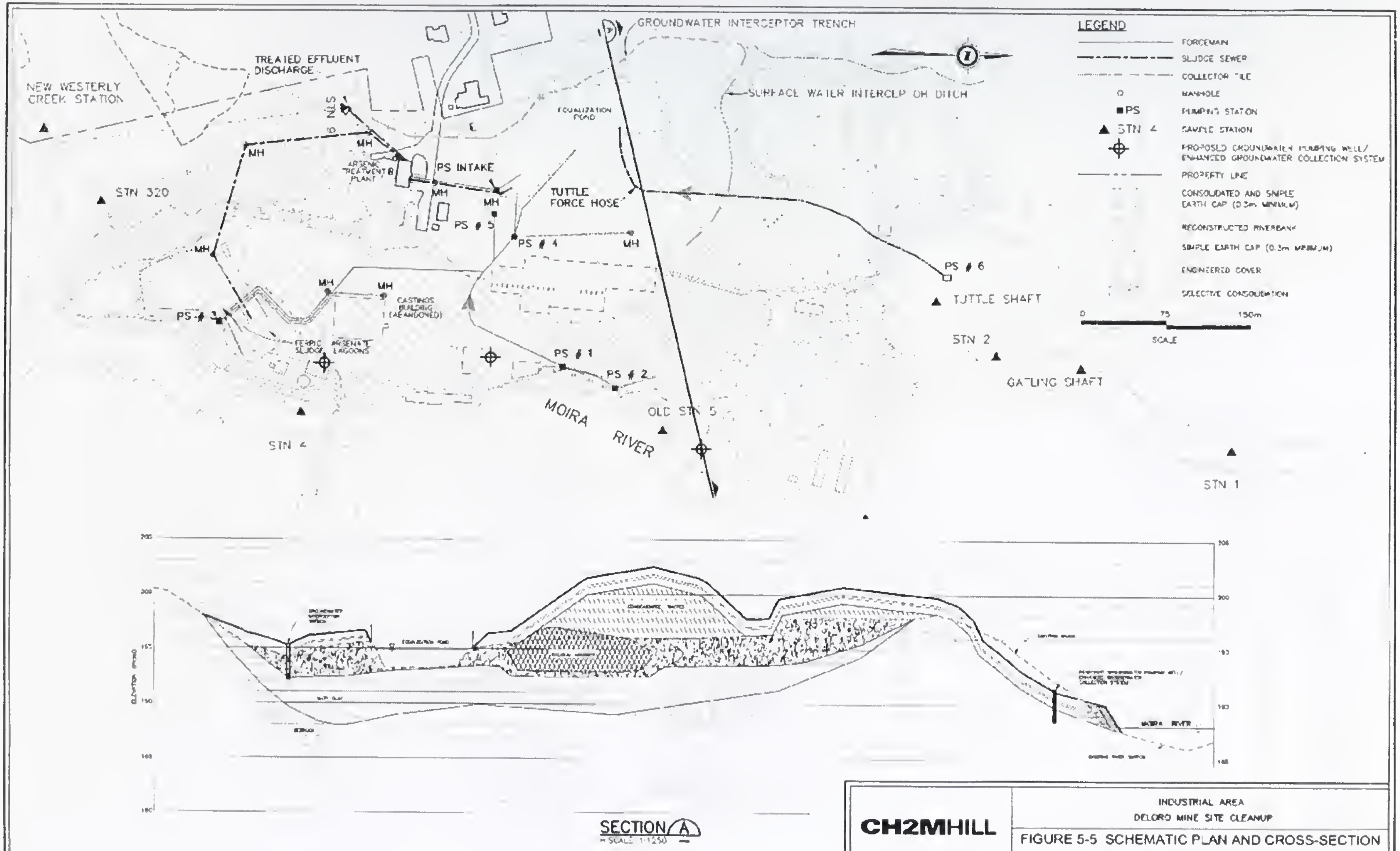

INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

CH2MHILL

FIGURE 5-5 SCHEMATIC PLAN AND CROSS-SECTION CONSOLIDATE AND COVER, GROUNDWATER FLOW DIVERSION, ENHANCED GROUNDWATER COLLECTION

PROJECT No. 1:9548

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Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion, Selected Stabilization/Solidification, Enhanced Groundwater Collection

This comprehensive remediation alternative combines the consolidation of wastes and the construction of an engineered cover over the wastes and simple earth covers over exposed areas, a groundwater interceptor trench and a surface water interceptor ditch. It also incorporates the stabilization/solidification of the 13,800 m^3 of calcium arsenite and calcium arsenite impacted soil/wastes and enhanced groundwater collection downgradient (i.e. to the east) of the waste consolidation area.

This alternative, with the exception of selected offsite disposal, includes all protection features described in the previous alternative. Consequently, the expected performance of the alternative with respect to satisfying the interim PWQO for dissolved arsenic concentration at the intersection of the Moira River and Highway 7 is very good, both for the short and long term.

Consolidate and Cover Wastes – Groundwater and Surface Water Flow Diversion, Selected Offsite Disposal, Enhanced Groundwater Collection

This last comprehensive remediation alternative combines all of the enhancing environmental protection features described above (with the exception of the selected stabilization/solidification) with the primary remediation method of consolidating and covering the wastes. The expected performance of this alternative to satisfy the interim PWQO for dissolved arsenic at the intersection of the Moira River and Highway 7 is very good for the same reasons discussed in the previous paragraphs. In this comprehensive remediation alternative, however, the most leachable wastes (i.e. the calcium arsenite and calcium arsenite impacted soil/wastes) are disposed offsite.

Cap/Cover in Place

The next series of comprehensive remediation alternatives are comparable to those described previously. However, the primary remediation method involved in the following comprehensive remediation alternatives involves building an engineered cover over the location where the presence of leachable wastes (like calcium arsenite) is documented and placing a simple earth cap over the remainder of the Industrial Area (without any consolidation of similar waste types). The comprehensive remediation methods that were considered are as follows:

- Cap/cover in place
- Cap/cover in place – Groundwater and surface water flow diversion
- Cap/cover in place – Groundwater and surface water flow diversion, selected stabilization/solidification
- Cap/cover in place – Groundwater and surface water flow diversion, selected offsite disposal
- Cap/cover in place – Groundwater and surface water flow diversion, enhanced groundwater collection
- Cap/cover in place – Groundwater and surface water flow diversion, selected stabilization/solidification, enhanced groundwater collection

- Cap/cover in place – Groundwater and surface water flow diversion, selected offsite disposal, enhanced groundwater collection

Figures 5-6 and 5-7, respectively, illustrate schematic plan and cross-section views of the Industrial Area and the engineered cover and simple earth caps.

The expected performance of these comprehensive remediation alternatives is comparable to the performance of the comprehensive remediation alternatives developed using the primary method of consolidating and covering the wastes described previously, particularly for the alternatives relying on the selected offsite disposal and/or selected stabilization/ solidification.

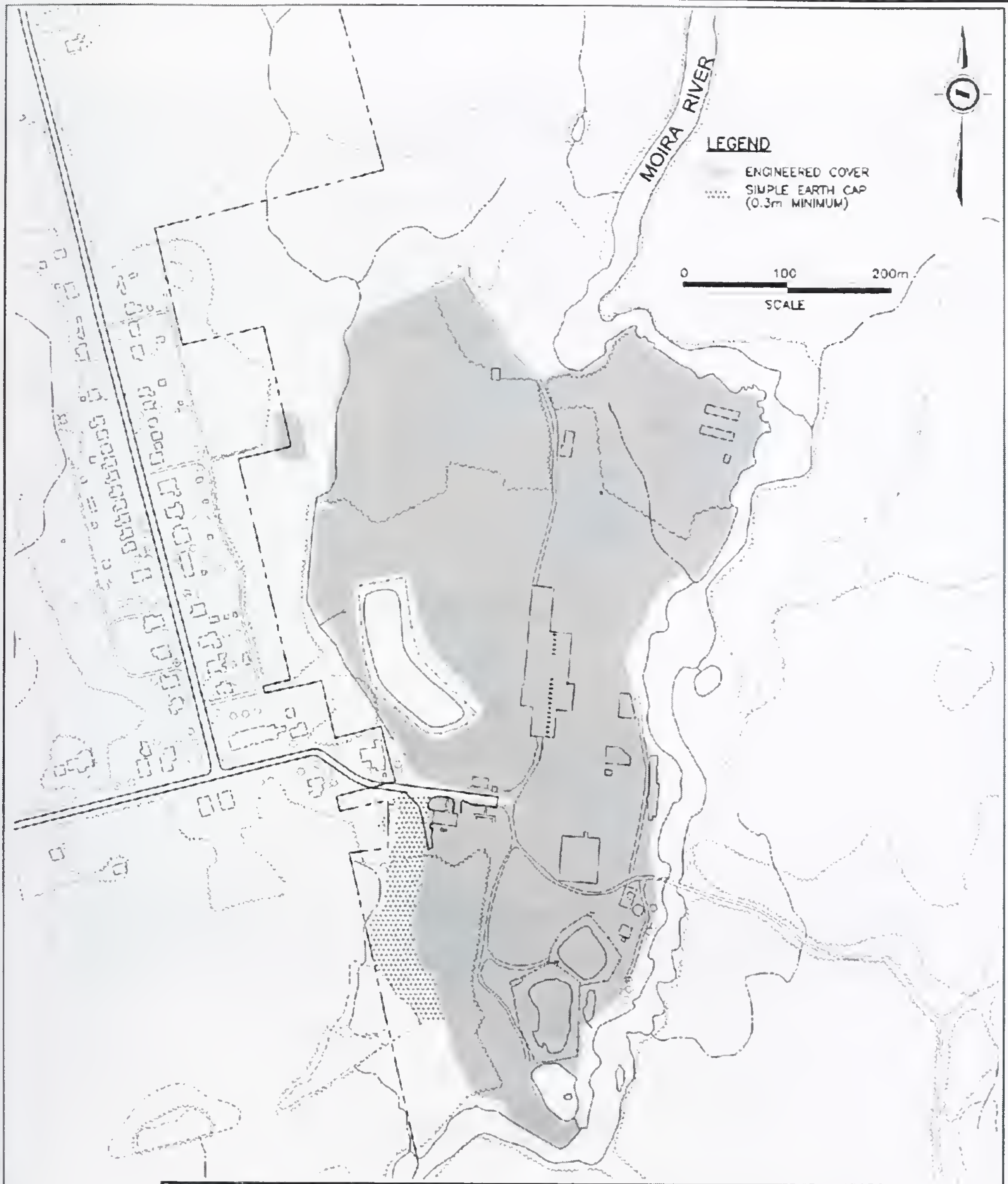
Full Encapsulation

This comprehensive remediation alternative involves the construction of a state-of-the-art secure containment cell in the central portion of the Industrial Area. The capacity of the waste storage cell required to accept all wastes and impacted soil from the Industrial Area is approximately 220,000 m^3. Such cells feature the construction of engineered final cover and base liner systems designed to prevent contaminant releases. The cover is typically vegetated. A typical final cover design features 150 mm of topsoil, 1,000 mm of compacted fill, a 300-mm sand drainage layer, and a geosynthetic clay liner to prevent infiltration of surface water. The geosynthetic clay liner (GCL) is embedded in a 500-mm sand layer which acts as a grading and cushioning layer. The cover is designed to promote runoff and evapotranspiration, thereby reducing the amount of precipitation that could come into contact with the wastes in the storage cell. The cover includes a drainage system to intercept any percolating water that does not runoff or is not evapotranspirated prior to reaching the wastes. This non-impacted infiltrating water collected in the cover system would be directed to either the New Westerly Creek or the Moira River.

The base liner system would consist of a leachate collection system bedded in a 300-mm sand drainage layer and a composite clay/high density polyethylene (HDPE) liner (1,000-mm). The leachate collection system would collect any water that penetrates the cover system and migrates through the wastes. The liquid collected by the leachate collection system would be collected in sumps and pumped to the equalization storage basin or directly to the onsite wastewater treatment plant.

The construction of such a cell in the Industrial Area would require significant double handling of the wastes in that area. The wastes would have to be excavated and removed from the area, segregated as a function of their physical and chemical characteristics and temporarily stockpiled in an adequate location for the duration of the period required for the construction of the cell, and transported a second time for final disposal into the cell. Environmental controls such as covering will be required with respect to the stockpiled wastes to prevent particulate transport by wind and leaching by precipitation.

The expected performance of this alternative in terms of satisfying the interim PWQO for dissolved arsenic concentration at the intersection of the Moira River and Highway 7 is very good as the wastes would be isolated from the environment and from the media through which contaminant migration could occur. Figure 5-8 shows a cross-section through a typical secure containment cell.



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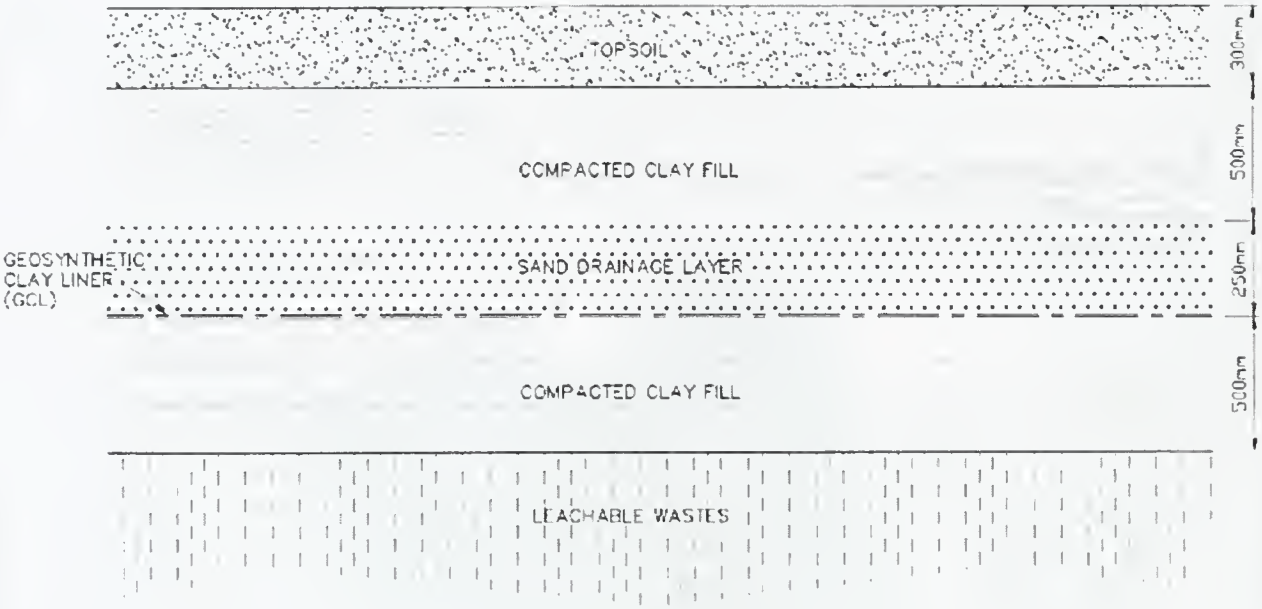
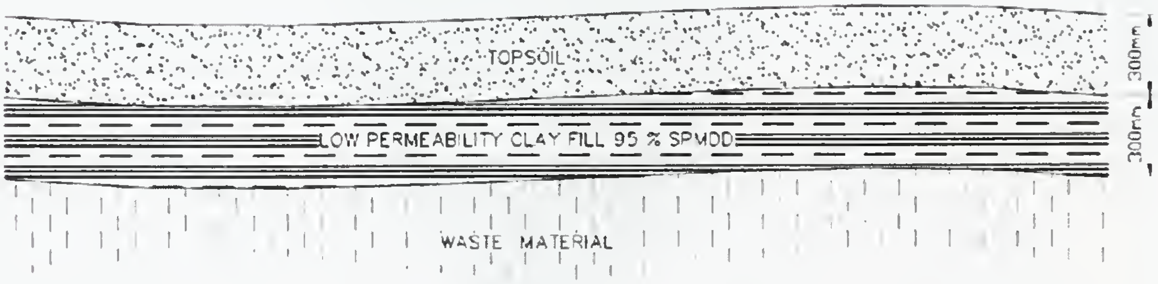
PROJECT No. 119548

INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 5-6
SCHEMATIC PLAN VIEW
CAP/COVER IN PLACE



ENGINEERED COVER
CONCEPTUAL DESIGN



SIMPLE EARTH CAP
CONCEPTUAL DESIGN

CH2MHILL	INDUSTRIAL AREA DELORO MINE SITE CLEANUP
PROJECT No. 119548	FIGURE 5-7 SCHEMATIC CROSS-SECTION CAP/COVER IN PLACE

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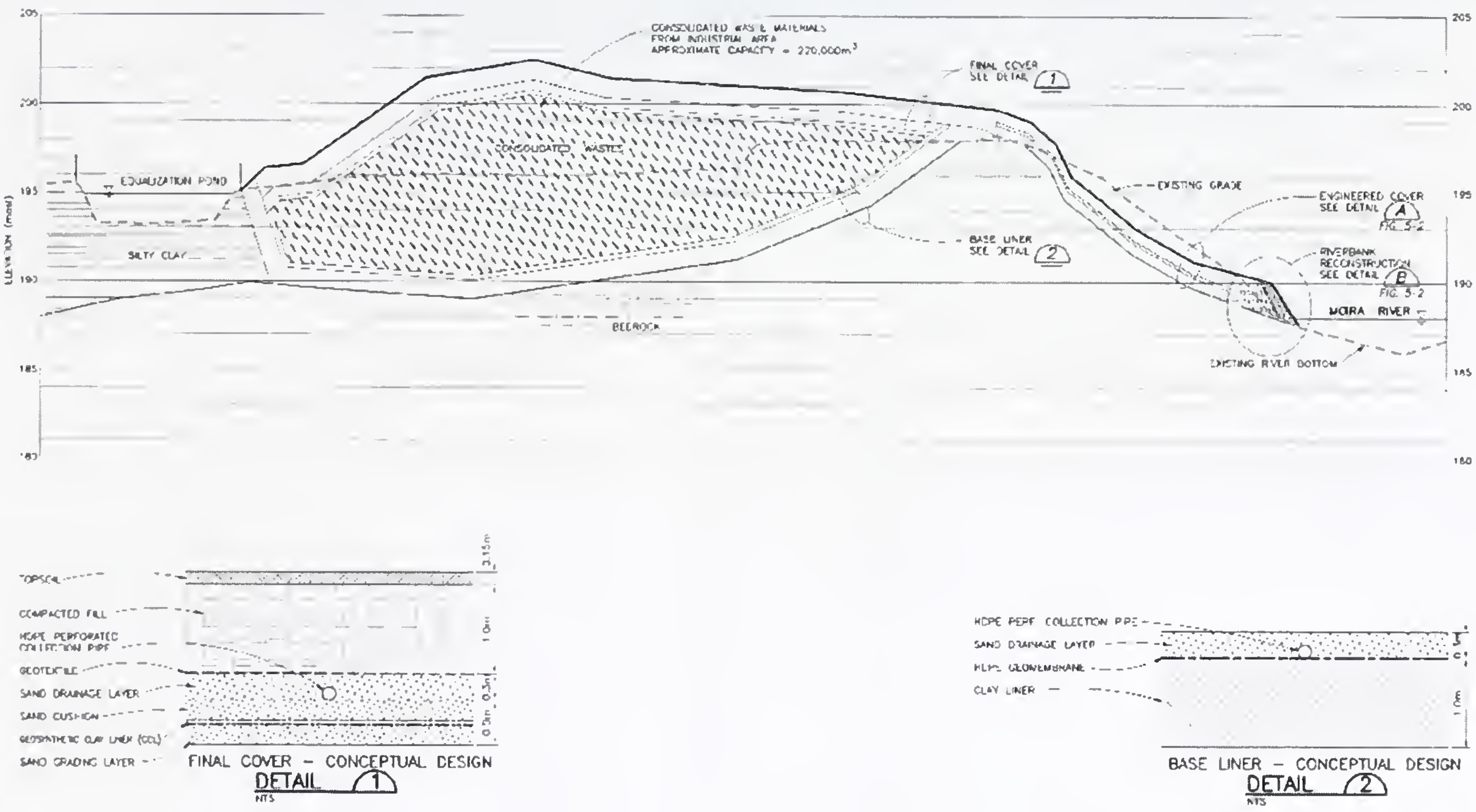

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INDUSTRIAL AREA
DELORO MINE SITE CLEANUP

FIGURE 5-8: CONCEPTUAL DESIGN FOR SECURE CONTAINMENT CELL SCHEMATIC CROSS-SECTION

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Full Encapsulation – Enhanced Groundwater Collection

This comprehensive remediation alternative combines the construction of a state-of-the-art secure containment cell, as described above, with the construction of additional groundwater withdrawal wells between the western shoreline of the Moira River and the containment cell. As in the alternatives previously presented, it has been assumed that three additional groundwater pumping wells will be installed east of the waste storage cell to accelerate the catchment of the arsenic groundwater plume that originates from the existing location of the leachable wastes. Following the construction of the containment cell, the volume of arsenic impacted groundwater that will continue to contribute arsenic to the Moira River will be limited to the groundwater that has moved through the wastes but that has not yet reached the existing groundwater collection system or the Moira River. The construction and operation of three additional pumping wells will enhance recovery of arsenic impacted groundwater by increasing the surface area over which groundwater withdrawal will occur. This will in turn reduce the period of time required to exhaust (or deplete) the arsenic impacted groundwater plume.

The expected performance of this comprehensive remediation alternative in terms of its potential to satisfy the interim PWQO for dissolved arsenic concentration at the intersection of the Moira River and Highway 7 is very good, as not only the main source of dissolved arsenic will be "cut off" by building a containment cell but the enhanced groundwater collection system should further decrease the current load of arsenic to the Moira River.

5.5.4 Additional Common Requirements

Regardless of the comprehensive remediation alternative that will be implemented in the Industrial Area, the following two aspects of the site will require particular attention:

- Demolition of existing structures
- Riverbank reconstruction (western shoreline of the Moira River through the Industrial Area)

Each aspect is described below as they are both an integral part of all comprehensive remediation alternatives for the Industrial Area as described above.

Demolition of Buildings and Infrastructure

Most of the former buildings at the Deloro Mine Site have been demolished to some extent. The majority of the remaining buildings are currently unused and are considered a potential safety hazard. Some of the structures, such as the castings building, contain variable quantities of waste material. There are also several other structures in various states of ruin. Except for the powerhouse building, which might figure into a potential heritage plan for the site, none of the buildings are considered to have any future value and their demolition is planned as part of the closure plans. All above-ground structures are to be demolished to ground level prior to the grading of the site, with the exception of the Arsenic Treatment Plant, which will remain on the site, and perhaps the concrete trestle piers of the former primary treatment buildings and portions of the castings building walls, which might also figure into a potential heritage plan for the site. Demolition materials that are uncontaminated may be used for erosion protection as part of the reconstruction of the riverbank. Contaminated demolition materials are to be consolidated and managed along with the bulk of the impacted fill materials.

In general, the non-contaminated wood wastes are not suitable for onsite consolidation beneath an engineered cover structure. The following options are currently proposed for the handling of the wood waste:

- Size reduction using a chipper or tub grinder; the resulting product would then be used as a conditioner in the topsoil and simple earth cap
- Onsite consolidation and composting in a suitable area

In addition to the buildings and infrastructure ruins, there is a large amount of rubble and waste spread in small piles about the Industrial Area, which should be collected to improve the general order of the site. All of the demolition materials should be size reduced wherever possible to improve the compaction qualities of the material.

The buildings and building ruins that will require demolition are listed below. Figure 2-2 shows the locations of the structures as they existed circa 1961.

- Castings building (shown as Casting Plant)
- Cobalt oxide plant (shown as Cobalt Oxide House)
- Cobalt packer house and plant dry building (not labelled)
- Arsenic packing shed (shown as Bag House and Packing House)
- Sludge lagoon ruins (shown as Nickel Plant 4 Warehouse and Locomotive Shed)
- Storage tanks (not labelled)
- Primary treatment building (shown as Primary Treatment Buildings)
- Boarding houses, hub, and kitchen (shown as Boarding House, Hub and Kitchen)
- Powerhouse (shown as Power House)
- Lab building (shown as Chemistry Laboratory)
- Old treatment plant (not labelled)

Riverbank Reconstruction

Bank remediation will be carried out along those sections of the Moira River where contaminated material is to be removed from the existing bank. Those sections of the river that require removal of existing material and subsequent reconstruction are indicated in Figure 5-1. The extent of the reconstructed section is approximately 620 metres, as noted in the report entitled *Deloro Mine Rehabilitation Project, Riverbank Reconstruction Alternatives for the Industrial Area, Final Report* (CH2M HILL, March 2002b).

The streambank reconstruction methods will maintain the configuration of the stream as closely as possible to existing conditions of bank height, bank slope, and available flood plain. Adequate sediment and erosion protection procedures will be undertaken during all phases of the construction to ensure adequate protection of the stream habitat.

The existing bank slopes vary from fairly gentle slopes at approximately 3:1 to steep slopes at 1:1 or near vertical. The bank material at the toe of the slope consists mainly of local cobble and stone in a range of sizes. This existing armouring has provided adequate erosion protection and prevented the river from experiencing any significant bank loss. The upper bank along the section of the river designated for reconstruction is, for the most part, lightly vegetated with local grasses and shrubs, which provide additional erosion protection to the top of the bank during flood flows.

The contaminated material comprising the existing bank will be removed, using standard techniques to minimize sediment suspension and transport, and stored onsite in a selected location above the 100-year flood elevation and adequately protected from washout of material through surface runoff. Material will be removed to a minimum of 5 metres distance from the existing riverbank. Removal of this material will provide for adequate contaminant removal and allow subsequent bank reconstruction that will ensure the stability of the reconstructed bank and the protection of the compacted clay berm placed adjacent to the contaminated waste material that will be left in place (CH2M HILL, March 2002b).

5.6 Detailed Evaluation of Short-Listed Alternatives

The 16 short-listed alternatives identified were compared to a set of detailed evaluation criteria that are designed to sort the characteristics of the comprehensive remediation alternatives to select a recommended remediation alternative. Table 5.3 summarizes the results of the evaluation process; details of the evaluation are provided below.

5.6.1 Technical Considerations

Reliability

This criterion evaluates the ability of the alternatives to satisfactorily control the discharge of arsenic to the Moira River. Four of the 16 short-listed comprehensive remediation alternatives were evaluated to be either "poorly" or only "fairly" reliable; these include the following:

- Consolidate and cover wastes
- Cap/cover in place
- Cap/cover in place – Groundwater/surface water flow diversion
- Cap/cover in place – Groundwater/surface water flow diversion, enhanced groundwater collection

The remainder of the comprehensive remediation alternatives were assessed to have the potential to satisfactorily control the discharge of arsenic to the environment. This potential increases with the increasing number of environmental protection features and particularly with the selected stabilization/solidification or the selected offsite disposal features which provide "permanent" solutions to the presence of very large quantities of leachable arsenic wastes onsite.

Compatibility with Existing System

All short-listed comprehensive remediation alternatives are estimated to be compatible with existing site conditions with the exception of the ones relying on the full encapsulation scenarios. The main reason for this is that full encapsulation requires double handling of all of the waste materials. Furthermore, these scenarios require the construction of temporary storage areas that will protect the excavated materials from the elements for the duration of the construction of the secure containment cell. Additional difficulties associated with theses scenarios are related to geotechnical conditions of the site in the vicinity of the existing equalization storage basin. Previous investigations (Trow, 1981a&b) have shown that a

bedrock "high" exists in the area where the waste storage cell would be constructed and that significant efforts were required to dewater silty sands located in the Industrial Area when the equalization storage basin was built in the early 1980s.

Ease of Implementation

The ease with which the various comprehensive remediation alternatives may be implemented varies significantly. Ease of implementation ranges from good to very poor. Alternatives that require little, if any, handling of wastes were deemed easily implementable (received a score of "good"). The alternatives relying on the primary remediation method of cap/cover wastes in place fit under this category. The ones that require significant onsite handling of the wastes received a score of "fair" when evaluated for this criterion. The alternatives that fall under this category rely mainly on the consolidate and cover wastes primary remediation method and the selected offsite disposal of the leachable calcium arsenite and calcium arsenite impacted soils/wastes. The alternatives that were ranked as "poor" under this criterion (regardless of the primary remediation method to which they are associated) include selected stabilization/solidification as the introduction of a stabilizing agent into the wastes is perceived as a significantly difficult task. Finally, the full encapsulation scenarios were evaluated to be "very poor" in terms of the ease of implementation because of the numerous constraints posed by these scenarios (e.g. double handling, very limited available surface area).

5.6.2 Costs

The capital and construction costs, the annual operation and maintenance costs, and the net present value costs associated with each alternative are summarized in Table 5.3. The breakdown of the various components of the total cost associated with each alternative is detailed in Appendix B; the major assumptions used in the cost opinions are also stated in that appendix. Because of the uncertainty in design requirements at this conceptual design stage, all costs provided should be considered as "cost opinions" at this stage to assist the MOE in selecting between comprehensive remediation alternatives.

The capital costs associated with the construction of the 16 comprehensive remediation alternatives varies from $10,205,500 to consolidate and cover the wastes to $25,343,500 to cap/cover the wastes in place coupled with a groundwater and surface water flow diversion system, selected offsite disposal of the calcium arsenite and calcium arsenite impacted soils/wastes and an enhanced groundwater collection system. Annual operation and maintenance costs for these alternatives range from $838,000 to $885,000. The net present value of these annual operation and maintenance costs range from $21,175,500 to $36,923,500.

The net present value calculations were based on an assumed effective interest rate of 5 percent and a planning horizon of 20 years. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

TABLE 5.3
EVALUATION OF SHORT-LISTED COMPREHENSIVE REMEDIATION ALTERNATIVES

Short-Listed Comprehensive Remediation Alternatives	Detailed Evaluation Criteria																Overall Relative Measure
	Technical Considerations			Costs[1]			Social Considerations						Natural Environment				
	Reliability	Compatibility with Existing System	Ease of Implementation	Annual O&M Costs	Capital Costs (millions)	Net Present Value Costs[2] (millions)	Public Acceptance (Level of Reservation)	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character (Impact)	Risk to Workers (Health and Safety)	Geochemistry (Improvement)	Terrestrial Habitats (Improvement)	Floodplain (Infringement)	Fish Habitats (Disruption)	
Consolidate and cover wastes	Fair	Good	Fair	$838,000	$10 21	$21 18	Moderate	Moderate	Low	Low to Moderate	Low	Moderate	Moderate	High	Low	Low	Unsatisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion	Moderate	Good	Fair	$838,000	$10 43	$21 41	Moderate to High	Moderate	Low	Low to Moderate	Low	Moderate	Moderate to High	High	Low	Low	Satisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, selected stabilization/ solidification	Good	Good	Poor	$838,000	$14 67	$25 64	High	Moderate	Low	Low to Moderate	Low	Moderate	High	High	Low	Low	Unsatisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, selected offsite disposal	Good	Good	Fair	$838,000	$20 12	$31 09	High	Moderate to High	Low	Low to Moderate	Low	Moderate	High	High	Low	Low	Satisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, enhanced groundwater collection	Moderate to Good	Good	Fair	$849,000	$10 53	$21 64	Moderate to High	Moderate	Low	Low to Moderate	Low	Moderate	Moderate to High	High	Low	Low	Satisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, selected stabilization/ solidification, enhanced groundwater collection	Very Good	Good	Poor	$849,000	$14 76	$25 87	High	Moderate	Low	Low to Moderate	Low	Moderate	Very High	High	Low	Low	Unsatisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, selected offsite disposal, enhanced groundwater collection	Very Good	Good	Fair	$849,000	$20 21	$31 32	High	Moderate to High	Low	Low to Moderate	Low	Moderate	Very High	High	Low	Low	Satisfactory
Cap/Cover in place	Poor	Good	Good	$874,000	$15 16	$26 60	Low	Low	Low	Low	Low	Low	Fair	High	Low to Moderate	Low	Unsatisfactory
Cap/Cover in place – Groundwater/surface water flow diversion	Fair	Good	Good	$874,000	$15 59	$27 03	Low	Low	Low	Low	Low	Low	Moderate	High	Low to Moderate	Low	Unsatisfactory
Cap/Cover in place – Groundwater/surface water flow diversion, selected stabilization/solidification	Moderate	Good	Poor	$874,000	$19 83	$31 27	Moderate to High	Moderate	Low	Low to Moderate	Low	Moderate	Moderate to High	High	Low to Moderate	Low	Unsatisfactory

TABLE 5.3
EVALUATION OF SHORT-LISTED COMPREHENSIVE REMEDIATION ALTERNATIVES

Short-Listed Comprehensive Remediation Alternatives	Detailed Evaluation Criteria																Overall Relative Measure
	Technical Considerations			Costs[1]			Social Considerations						Natural Environment				
	Reliability	Compatibility with Existing System	Ease of Implementation	Annual O&M Costs	Capital Costs (millions)	Net Present Value Costs[2] (millions)	Public Acceptance (Level of Reservation)	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character (Impact)	Risk to Workers (Health and Safety)	Geochemistry (Improvement)	Terrestrial Habitats (Improvement)	Floodplain (Infringement)	Fish Habitats (Disruption)	
Cap/Cover in place – Groundwater/surface water flow diversion, selected offsite disposal	Moderate	Good	Fair	$874,000	$25.25	$36.69	Moderate to High	Moderate to High	Low	Low to Moderate	Low	Moderate	Moderate to High	High	Low to Moderate	Low	Satisfactory
Cap/Cover in place – Groundwater/surface water flow diversion, enhanced groundwater collection	Fair	Good	Good	$885,000	$15.68	$27.26	Moderate	Low	Low	Low	Low	Low	Moderate	High	Low to Moderate	Low	Unsatisfactory
Cap/Cover in place – Groundwater/surface water flow diversion, selected stabilization/solidification, enhanced groundwater collection	Good	Good	Poor	$885,000	$10.92	$31.50	Moderate to High	Moderate	Low	Low to Moderate	Low	Moderate	High	High	Low to Moderate	Low	Unsatisfactory
Cap/Cover in place – Groundwater/surface water flow diversion, selected offsite disposal, enhanced groundwater collection	Good	Good	Fair	$885,000	$25.34	$36.92	High	Moderate to High	Low	Low to Moderate	Low	Moderate	High	High	Low to Moderate	Low	Satisfactory
Full encapsulation	Very Good	Very Poor	Very Poor	$838,000	$11.97	$22.93	Moderate to High	Moderate to High	Low	Moderate	Low	High	Very High	High	Low	Low	Unsatisfactory
Full encapsulation – Enhanced groundwater collection	Very Good	Very Poor	Very Poor	$849,000	$12.08	$23.19	Moderate to High	Moderate to High	Low	Moderate	Low	High	Very High	High	Low	Low	Unsatisfactory

[1]Capital costs include GST and a 15% contingency (before taxes, overhead, insurance, and bonds) and operation and maintenance costs include GST and a 5% contingency (before taxes)
See Appendix B for a more detailed breakdown including overhead, insurance, and bond cost estimates

[2]Net present value costs assumed an effective interest rate of 5 percent and a time horizon of 20 years

Note Expected cost accuracy is +50%/-30%

5.6.3 Social Considerations

Public Acceptance

The spectrum of public acceptance of the various comprehensive remediation alternatives is very wide. The degree of public acceptance is evaluated to be lower for the alternatives that include fewer environmental protection features and stronger for the ones that provide several such features, particularly for the ones that include features that provide long term solutions with respect to the control of arsenic release to the environment (i.e. selected stabilization/solidification and selected offsite disposal).

Risk to Public

The risk to public health and safety varies with the degree of waste handling inherent to each of the comprehensive remediation alternatives. Alternatives that require little or no handling of the wastes are deemed to represent lower risks to the public. Such alternatives include the following: selected stabilization/solidification (in-situ), cap/cover wastes in place (without environmental protection features that call for waste handling). At the other end of the spectrum, comprehensive remediation alternatives that require extensive waste handling in terms of additional environmental protection features (i.e. selected stabilization/solidification (ex-situ), selected offsite disposal) were evaluated to represent a moderate to higher risk to public safety and will require special health and safety measures during remediation work.

Constraint for Recreational Use

The potential for the comprehensive remediation alternatives to have an impact on recreational activities is low, as the Deloro Mine Site is not accessible to the public. Regardless, should that condition change in the years to come, the waste materials will effectively be isolated by either an engineered cover and simple earth caps or a secure containment cell.

Negative Impact to Private Properties

All comprehensive remediation alternatives are anticipated to have low to moderate impact on private properties, particularly during the implementation stage of the selected alternative. Examples of short-term impacts are noise, dust generation and increased vehicular traffic. These short-term negative impacts are compensated by long-term positive effects such as minimization and control of contaminant release to the environment and significant improvement to the visual character of the area. However, as it is anticipated that a large volume of soil and aggregates will be brought onsite, measures will have to be implemented to minimize short-term disturbances caused by vehicular traffic through the Village of Deloro (e.g. trucking hours, use of tarps on trucks to minimize dust generation, truck washing station at the exit of the site, sweeping the road used by trucks to haul aggregates as required and compliance with municipal by-laws governing noise and construction site activity times).

Visual Character of the Area

All of the comprehensive remediation alternatives will result in a significant improvement to the visual character of the Industrial Area.

Risk to Workers

Risk to the workers is mainly associated with two sources in the Industrial Area. The first is linked to the use of heavy machinery used for the consolidation, covering and/or capping of the wastes or equipment required for the stabilization/solidification of the wastes. The second source of risk is linked to the potential exposure to contaminants. Both risks combined were evaluated to result in a moderate level of overall health and safety risks. Measures will have to be implemented to minimize these risks such as the proper use of protective personal equipment.

5.6.4 Natural Environment

Geochemistry

All comprehensive remediation alternatives described above improve the geochemistry of the Industrial Area. Comprehensive remediation alternatives that combine features that prevent or minimize contact between surface water, groundwater, and the atmosphere with the wastes provide a higher degree of improvement than the ones that do not.

Terrestrial Habitats

The current state of the terrestrial habitat in the Industrial Area can be described as poor given that various wastes (slag covered calcium arsenite pile, demolition debris, slag etc.) cover a large portion of the Area. With the exception of the selected stabilization/ solidification (as stand alone remediation alternatives) scenarios, the implementation of any of the comprehensive remediation alternatives is expected to result in a significant improvement of terrestrial habitat conditions because all of the alternatives involve covering and capping of the wastes with the subsequent introduction of vegetation.

Floodplain

All comprehensive remediation alternatives include a similar work component designed to remove the wastes currently present in the 100-year floodplain located on the western shoreline of the Moira River crossing the Industrial Area. Therefore, although the implementation of any remediation alternative will cause short-term disruption of the mentioned section of the floodplain, the latter will largely benefit from the remediation work.

Fish Habitats

The comprehensive remediation alternatives described above do not include work directly in fish habitat; however, it is expected that rehabilitation of the floodplain as described above may have minimal impact on fish habitat adjacent to the work area in the floodplain. Measures will have to be implemented to effectively minimize such impacts (e.g. timing of work, runoff and sediment control measures, etc.). Ultimately, work on the floodplain is expected to be beneficial to fish habitat because a significant proportion of the western shoreline of the Moira River in the Industrial Area will be "re-naturalized" as a result of the removal of wastes from the floodplain.

5.7 Selection of Recommended Remediation Alternative

In light of the information presented above, it appears that the leaching of arsenic into the environment at the Deloro Mine Site can be effectively controlled in the short-term to the long-term, by limiting availability of the wastes to the elements (i.e. wind, surface water, and groundwater), provided that the necessary operation and maintenance requirements are addressed (see Section 6.2). Furthermore, the basic principle of minimizing the footprint of the wastes, thereby reducing the potential area over which leachate resulting from the infiltration of precipitation can occur while at the same time minimizing the surface area of wastes through which groundwater may migrate, is sound.

Considering the above, the following decisional aides were followed in the selection of the recommended alternative:

- With respect to "Technical Considerations" alternatives with a rating of "poor" or "fair" under the criterion of "Reliability" were judged unsatisfactory and alternatives with a rating of "poor" under the "Compatibility with Existing System" or "Ease of Implementation" criteria were also judged to be unsatisfactory.
- As a result, only six of the comprehensive remediation alternatives were judged to be satisfactory.

The last column in Table 5.3 (i.e. Overall Relative Measure) indicates the "satisfactory" and "unsatisfactory" designations for the 16 short-listed comprehensive remediation alternatives based on the application of the above decisional aides. Table 5.4 summarizes the results of the evaluation process for the six satisfactory comprehensive remediation alternatives.

The next step in identifying the recommended alternative involved the following decisional aides:

- With respect to "Social Considerations" alternatives with fewer or smaller social impacts were favored over the ones with a greater number or larger social impacts.
- With respect to the "Natural Environment" alternatives with greater positive impacts on the natural environment were favored.
- With respect to "Costs", the net present value for the six satisfactory comprehensive remediation alternatives was considered to determine the most cost effective alternative which provided an adequate level of control of contaminant release to the environment.
- Finally, the potential to add contingency measures (if required) to the satisfactory alternatives was also evaluated.

Several iterations of the decisional process resulted in the selection of the following comprehensive remediation alternative: Consolidate and cover wastes – Groundwater and Surface Water Flow Diversion. This comprehensive remediation alternative is the most economical of the ones that were evaluated to be satisfactory at a net present value of $21,404,500. In principle, it has the potential to minimize contaminant migration to the environment and is amenable to the addition of contingency features if required.

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TABLE 5.4
EVALUATION OF SHORT-LISTED COMPREHENSIVE REMEDIATION ALTERNATIVES WITH SATISFACTORY RATING

Short-Listed Comprehensive Remediation Alternatives	Detailed Evaluation Criteria															Potential to Add Contingency Measures (if required)	Overall Relative Measure
	Technical Considerations			Costs[1]			Social Considerations						Natural Environment				
	Reliability	Compatibility with Existing System	Ease of Implementation	Annual O&M Costs	Capital Costs (millions)	Net Present Value Costs[2] (millions)	Public Acceptance (Level of Reservation)	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character (Impact)	Risk to Workers (Health and Safety)	Geochemistry (Improvement)	Terrestrial Habitats (Improvement)	Floodplain (Infringement)	Fish Habitats (Disruption)		
Recommended Alternative: Consolidate and cover wastes – Groundwater/surface water flow diversion	Moderate	Good	Fair	$838,000	$10.43	$21.41	Moderate to High	Moderate	Low	Low to Moderate	Low	Moderate	Moderate to High	High	Low	Low	Moderate	Satisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, selected offsite disposal	Good	Good	Fair	$838,000	$20.12	$31.09	High	Moderate to High	Low	Low to Moderate	Low	Moderate	High	High	Low	Low	Moderate	Satisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, enhanced groundwater collection	Moderate to Good	Good	Fair	$840,000	$10.53	$21.64	Moderate to High	Moderate	Low	Low to Moderate	Low	Moderate	Moderate to High	High	Low	Low	Moderate	Satisfactory
Consolidate and cover wastes – Groundwater/surface water flow diversion, selected offsite disposal, enhanced groundwater collection	Very Good	Good	Fair	$840,000	$20.21	$31.32	High	Moderate to High	Low	Low to Moderate	Low	Moderate	Very High	High	Low	Low	Moderate	Satisfactory
Cap/Cover in place – Groundwater/surface water flow diversion, selected offsite disposal	Moderate	Good	Fair	$874,000	$25.25	$30.69	Moderate to High	Moderate to High	Low	Low to Moderate	Low	Moderate	Moderate to High	High	Low to Moderate	Low	Moderate	Satisfactory
Cap/Cover in place – Groundwater/surface water flow diversion, selected offsite disposal, enhanced groundwater collection	Good	Good	Fair	$885,000	$25.34	$30.92	High	Moderate to High	Low	Low to Moderate	Low	Moderate	High	High	Low to Moderate	Low	Moderate	Satisfactory

[1] Capital costs include GST and a 15% contingency (before taxes, overhead, insurance, and bonds) and operation and maintenance costs include GST and a 5% contingency (before taxes)
See Appendix B for a more detailed breakdown including overhead, insurance, and bond cost estimates

[2] Net present value costs assumed an effective interest rate of 5 percent and a time horizon of 20 years

Note: Expected cost accuracy is +50%/-30%

6. Recommended Remediation Alternative

In the previous sections, comprehensive remediation alternatives were developed, evaluation criteria were identified and the remediation alternatives were evaluated with respect to these criteria and site-specific conditions.

6.1 Key Components of the Recommended Alternative

The recommended alternative for meeting site closure objectives was based on minimizing the footprint of the leachable wastes in the Industrial Area, protecting these wastes from the elements by encapsulating them under an engineered cover designed to minimize infiltration, and, by diverting groundwater from the wastes and surface water from the engineered cover. Portions of the Industrial Area where less leachable wastes will remain (e.g. the slag and construction debris) will be covered by a simple earth cap.

6.1.1 Site Preparation

Prior to commencing the remediation work, site preparation work will be completed that includes mobilization of equipment (excavators, trucks, site trailers, and other equipment), construction of access roads and establishment of temporary services.

6.1.2 Construction of Engineered Cover

The preferred choice of engineered cover consists of layers of topsoil, sand, and compacted clay fill materials in combination with a geosynthetic membrane. The topsoil provides the initial rooting medium for the proposed vegetation. The compacted clay fill layer functions as a restricting layer to minimize infiltration of water into the wastes. Based on the findings of previous work, it is possible, using such a design, to minimize infiltration into the wastes by maximizing runoff and evapotranspiration.

6.1.3 Construction of Groundwater and Surface Water Interceptor Trench/Ditch System

The addition of these features to the primary remediation method of building an engineered cover over the leachable wastes is designed to prevent the flow of groundwater through the lowest portion of the consolidated wastes by lowering the watertable below the base of the wastes. The current understanding of the groundwater flow system for the vicinity of the Deloro Mine Site suggests that groundwater flows from the west to the east across the Industrial Area. Therefore, it is anticipated that the construction of the proposed groundwater interception trench on the western section of the site (i.e. upgradient of the waste consolidation area) will intercept the main source of groundwater inflow to the Industrial Area. The same rationale applies for the proposed surface water interception ditch to be constructed to the north of the waste consolidation area.

6.2 Operation and Maintenance Requirements

Operation and maintenance efforts under the recommended alternative will be associated primarily with the ongoing operation of the arsenic groundwater collection and treatment system and the disposal of sludge stored in the ferric arsenate sludge lagoon. Other maintenance efforts will include periodic maintenance of the simple earth cap, engineered cover, surface water interceptor ditch, and reconstructed riverbank to repair any erosion damage and areas of vegetative stress.

Monitoring efforts will be focussed on the monitoring of surface water and groundwater and biomonitoring, if required, at selected locations, to evaluate the effectiveness of the recommended alternative following implementation.

A detailed operations and maintenance plan should be established for the recommended alternative following implementation.

6.3 Cost Opinion

A breakdown of the estimated costs associated with the recommended alternative is provided in Appendix B and is summarized below in Table 6.1. The costing in Appendix B has been completed at the conceptual design level and should be considered as a "cost opinion" to assist in selecting a preferred alternative. Costs can further be defined, once the preferred remediation alternative has been selected and a detailed design and approach is developed.

TABLE 6.1
ESTIMATED COSTS FOR IMPLEMENTING RECOMMENDED ALTERNATIVE

Cost Item	Estimated Cost
Capital Cost Items	
1. Site preparation	$204,000
2. Demolition	$729,500
3. Riverbank Reconstruction	$852,000
4. Consolidate and Cover Wastes	$7,625,000
5. Groundwater/Surface Water Flow Diversion	$211,000
6. Overhead, Insurance, and Bonds	$813,000
Total Capital Costs	**$10,434,500**
Operation and Maintenance Cost Items (Annual)	
1. Plant Operations Costs	$550,000
2. Sludge Disposal Costs	$170,000
3. Site Maintenance Costs (Cap and General)	$78,000
4. Contingency (5% for items 1 to 3)	$40,000
Total Annual O&M Costs	**$838,000**
Net Present Value O&M Costs	**$10,970,000**
Net Present Value of Capital and O&M Costs	**$21,404,500**

The net present value costs presented above are the sum of the capital cost and the net present value of the operation and maintenance costs. The annual operation and maintenance costs have been transformed to a net present value assuming an effective interest rate of 5 percent and a planning horizon of 20 years. The effective interest rate includes inflationary effects. It should be noted that operation and maintenance effort and costs will be required beyond the 20 year horizon. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

As shown above, the estimated capital cost for the recommended alternative is $10,434,500 with annual operation and maintenance costs of $838,000. The net present value of the recommended alternative is $21,404,500.

6.4 Data Gaps

The selection of the recommended remediation alternative is based on the basic principle that the leachable wastes from the Industrial Area should be isolated from media susceptible to promote transport and release of the contaminants to the environment. However, considering the relative complexity of conditions in the Industrial Area (i.e. complex blend of wastes and impacted materials, numerous geological and hydrogeological units, bedrock outcropping, etc.), several unknowns must be resolved prior to the implementation of the recommended, or any other, remediation alternative. These unknowns, referred to here as data gaps are identified and described below.

6.4.1 Identification of the Arsenic Species

Arsenic trioxide (As_2O_3) was a byproduct of the smelting and refining operations conducted at the site up to the late 1950s. It was sold on its own or used onsite to make pesticides. Arsenical-based pesticides gave way to organic pesticides in the late 1950s and, as a result, tonnes of arsenic (trioxide) were stockpiled onsite. It appears that, to stabilize the arsenic trioxide, lime was added to it to form calcium arsenite. The resulting compound was stockpiled on the site. Because the formation of calcium arsenite would have required an additional step in the stabilization process it is doubtful that this extra step (involving extra costs) would have been taken. However, recent chemical/mineralogical identification work performed on the "white powder" suggests that the stockpile's composition is heterogeneous (there seems to be an abundance of calcium) and that this may have had an impact on the previous interpretation of analytical results.

Because the environmental fate of the "white powder" can only be determined with some degree of accuracy if its chemical/mineralogical nature is known, work to establish these characteristics should be conducted prior to any remediation work. Furthermore, because of its high toxicity and the fact that it was once manufactured at the site, the analytical work performed on the "white powder" should include a determination of its arsenic content.

6.4.2 Bioavailability of the Contaminants Present in the Waste Streams

The primary objective of any remediation alternative is to minimize human health and ecological risk by isolating, neutralizing or transforming contaminants. The level of risk associated with the presence of the wastes in the Industrial Area is not necessarily correlated to the arsenic concentration of the wastes but it is, in fact, governed by the degree of bioavailability of the contaminants present in the wastes. Measurements of contaminant

bioavailability should consequently be conducted on the main waste streams present in the Industrial Area (e.g. "white powder", slag, impacted fill, gold mine tailings, and others) and integrated in the Site Specific Risk Assessment (SSRA) studies currently being conducted. Two recent methods that rely on iterative sequential chemical (acidic) extractions are currently used in this field to determine bioavailability. They are known as the Sequential Selective Extraction Method and the Gastric Fluid Model. Discussions should be held with regulatory agencies prior to conducting bioavailability studies to ensure that they will be completed in conformity with the expectations of the agencies.

Results of the bioavailability studies may translate into substantial cost savings for the implementation of the selected remediation alternative particularly if it is demonstrated that the bioavailability of certain wastes is low or negligible.

6.4.3 Detailed Groundwater Modelling

One of the key features of the recommended remediation alternative involves the construction of a groundwater flow diversion trench at the western property boundary of the Industrial Area to maintain the watertable in the area where the wastes will be consolidated below the base of the wastes. It is known that geological and hydrogeological parameters in the Industrial Area are complex, resulting from both natural and constructed conditions. Because watertable elevation control is very important to the recommended alternative, detailed groundwater modelling of current, and post-remediation conditions should be conducted in conjunction with the development of detailed cleanup plans. The potential to create vertically upward hydraulic gradients under the waste consolidation area should be investigated as well as the impact of a relatively deep groundwater interception trench on private wells located in the vicinity of the site. This may require acquisition of additional field data (e.g. groundwater levels, additional monitoring well nests, etc.).

Likewise the exact number and location of additional groundwater pumping wells (to build an enhanced groundwater withdrawal system for instance) will only be determined as a result of such a modelling exercise.

6.4.4 Long-Term Solidification/Stabilization of the "White Powder"

The recommended alternative has the potential to satisfy the closure objectives for the Industrial Area. Unfortunately the nature of the most leachable arsenic containing wastes is such that the potential environmental problems associated with their presence will not decrease with time and, consequently, the engineered cover and groundwater and surface water interception trench/ditch will require periodic maintenance work in perpetuity (or until a commercial technology becomes available to permanently dispose/treat/transform these wastes).

As part of this update to the remediation alternatives for the Industrial Area, CH2M HILL has repeatedly attempted to quantify costs associated with the onsite stabilization/ solidification (in-situ and ex-situ) of the up to 14,000 m^3 of white powder (calcium arsenite) and white powder impacted wastes and soil. A recurrent difficulty has prevented CH2M HILL from performing this task in a detailed fashion. The difficulty in question stems from the lack of data about the treatability of the particular arsenic containing wastes. Vendors of the stabilization/solidification technology re-iterated that cost estimates provided were derived from experience with a multitude of contaminants/waste types and should be regarded as Class "D" estimates only. (A Class "D" estimate is based upon a

statement of general requirements and an outline of a conceptual solution. It is an order of magnitude estimate with a degree of accuracy of +50% / –30%.) Furthermore, information provided by a research scientist, member of the Technical Advisory Committee retained for the completion of this update, suggests that typical loads of wastes/contaminants into stabilization/solidification agents may be significantly smaller for the arsenite/arsenate waste present at the Deloro Mine Site than typical loads of other contaminants more commonly dealt with by vendors in the industry. This implies that to ensure the final stability of the arsenite/arsenate waste/stabilizing agent mix, the actual proportion of the waste into the mix may have to be as low as 10 percent (typically waste concentrations in the waste/stabilizing agent mix can be as high as 80 percent to 95 percent), which in turn implies that the actual volume of stable but dilute waste generated by this process could be as high as ten times the original volume of waste. However, the above remains somewhat speculative until laboratory stabilization/ solidification tests are performed on representative samples of the arsenite/arsenate wastes. Additional detailed information would be required to determine the exact physical conditions of the waste materials buried onsite as this has significant bearing on the applicability of in-situ technologies and the need for pre-treatment should onsite, ex-situ applications be considered. Filling the data gaps is particularly relevant if the MOE wishes to have all elements necessary to perform a more detailed analysis of the cost/benefit ratio of this technology.

6.5 Demolition of Existing Buildings and Infrastructure

A number of buildings must be demolished as part of the Deloro Mine Site Cleanup. The following is a brief description of the demolition work that is required.

6.5.1 Castings Building

The largest of the remaining structures is the castings building. The 35 m by 43 m brick building rests on a sloping concrete foundation. The interior of the building is fabricated with open web steel joists to support the roof and wide flange steel columns to sustain the weight of the building envelope. All of the glass has been removed from the window openings. The roof is constructed of a timber deck over timber stringers and has partially collapsed in some areas. Although the castings building has been identified by the MOE as one of the buildings for heritage potential, the majority of the structure is unusable and requires demolition. However, heritage usage may involve the restoration of portions of the walls.

There is potential to recycle much of the demolition debris from this building. It is possible for a contractor to maintain control over mixing of the recoverable scrap metals with wood waste and brick rubble. Several waste drums and several bags of lime remain within the building: these should be removed and either disposed offsite or crushed, consolidated and managed onsite with wastes of similar character.

The eastern addition (metals plant) of the castings building has already been demolished. An excavator with an experienced operator would be capable of sorting through the existing rubble and recovering several loads of scrap metal.

Sections of the floor are located over a crawl space. Where possible, the floor should be caved in to ensure that the best possible compaction is achieved during construction. The crawl spaces may have to be filled with a controlled low strength material to ensure they do

not compromise the integrity of the engineered cap or create any preferential pathway for groundwater flow.

6.5.2 Cobalt Oxide Plant

Several concrete structures remain from the cobalt oxide plant, which covered an area of approximately 62 m by 46 m. Thick diamond meshed reinforced concrete foundation members were left standing from the original demolition. These structures have many conduits and open void spaces. The void space will need to be eliminated to ensure proper compaction can be achieved. This will likely involve the combined effort of small explosive devices and an excavator with a hydraulic breaker to demolish the remains to ground level.

6.5.3 Cobalt Packer House and Plant Dry Building

Brick rubble and wood waste is all that remains of these two buildings. A borehole in this area uncovered what seems to a lense of calcium arsenite. Test results indicate arsenic concentrations of 2,800 ppm in this area.

6.5.4 Arsenic Packing Shed

The arsenic packing shed has already been demolished. A large amount of wood waste is present in this area.

6.5.5 Sludge Lagoon Ruins

The remains of three foundations are located adjacent to the east side of the active ferric arsenate sludge lagoon. These foundations must be removed to ground level and consolidated.

6.5.6 Storage Tanks

There are two metal storage tanks that have been recessed into concrete vaults. The tanks need to be pumped, cleaned, and removed. The surrounding concrete storage vaults will need to be demolished to grade or completely removed. A third tank remains beside the former cobalt oxide plant foundation. This tank will need to be cut, crushed, or removed from the site as is.

6.5.7 Primary Treatment Building

Several heavy demolition tasks will take place in this area. In order to ensure proper grade slopes, all structures above the 198 masl (refinery slab) grade line must be demolished. The eleven concrete trestle piers on the former primary treatment building slab have been identified by the MOE for heritage potential. The trestle piers are heavily reinforced concrete and span a total distance of 97-m. Should it be determined that the trestle piers will not be preserved, the demolition work should probably allow for the use of an excavator with a hydraulic breaker assembly without any significant preparatory work being performed. The remains of the elevator shaft should be demolished to the ground. The shaft will also need to be pumped and filled with grout to seal the void. The shaft is approximately 5 m deep and will need a retaining wall at the bottom to restrict the flow of grout to the shaft. Small support walls and non-structural members are present at the north end of the deck. These will also need to be demolished to grade. A parapet lines the eastern and interior walls. This parapet will require removal in order to establish a level surface.

A suspended slab is present at the east end of the primary treatment area. The portion of the slab that is overhanging the lower wall is being held in place by corrugated plate and wide flange beams. The beams can be recycled and the fallen slab could be consolidated with the rest of the waste materials. The remainder of the slab has been set on a checker plate base supported by wide flange beams. The remainder of the slab should be removed along with its corresponding metal members.

There is a receiving bay at the northeast end of this building area. The walls are approximately 0.5 m wide and heavily reinforced. These walls will need to be demolished until there is no threat of the void space compromising the engineered cap function.

6.5.8 Boarding Houses, Hub, and Kitchen

Concrete foundations remain from the former boarding houses near the Deloro falls. These foundations can be easily reduced to ground level. Much of the area has been littered with empty barrels and piles of slag. The barrels should be crushed in order to reduce volume. They can then either be recycled or consolidated. The slag should be consolidated in the central Industrial Area.

A 36 m by 15 m concrete slab and lower wall still remain of the Hub dining room. The slab was poured over the bedrock outcrop adjacent to the road leading to the Tuttle Shaft. It may be possible to cap the remains of the Hub in place.

6.5.9 Powerhouse

The powerhouse is a two-storey, free-standing building constructed of cut limestone blocks. The building measures 8.5 m by 11 m. The northwest corner of the building shows signs of minor differential settlement. The powerhouse is one of the buildings which has been identified by the MOE for heritage potential. Should it be determined that it will not be preserved, the limestone blocks can be crushed and used as fill onsite.

6.5.10 Lab Building

The lab building has already been demolished. It was a two-storey, flat-roofed building constructed of concrete blocks, brick, and clay tiles. The dimensions of the building were 21 m by 20 m. The wood waste can be separated from the other materials and perhaps size reduced in a tub grinder. The remaining waste can be consolidated. A concrete foundation remains and can be removed by use of an excavator with a hydraulic breaker. This location will require the foundation to be completely removed. The foundation is on bedrock and the location is close in proximity to the main entrance.

6.5.11 Old Treatment Plant

This one storey wood structure held a ferric chloride tank for the original treatment of the arsenic bearing waters. The building is approximately 10 m by 20 m and should be demolished to ground level. All the wood wastes can be disposed of in a manner similar to that mentioned above.

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Appendix A
MOE EA Criteria

Table A.1
Relationship Between Detailed Evaluation Criteria and Environmental Assessment Screening Criteria

Environmental Assessment Screening Criteria	Detailed Evaluation Criteria									
	Social Considerations						Natural Environment			
	Public Acceptance	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character of the Area	Risk to Workers	Geochemistry	Terrestrial Habitats	Floodplain	Fish Habitats
Affect air quality	x	x	x	x		x		x		
Affect water quality or quantity (ground or surface)									x	x
Affect species at risk or their habitat								x		x
Affect significant earth or life science features							x	x	x	x
Affect fish or other aquatic species, communities, or habitat									x	x
Include or use land subject to natural or human-made hazards										
Affect the recovery of a species under a special management program (e g elk restoration)										
Affect ecological integrity							x	x	x	x
Affect terrestrial wildlife or habitat, linkages or corridors (including movement of resident or migratory species)								x	x	
Affect natural vegetation and habitat through fragmentation								x	x	x
Affect permafrost										
Affect drainage, sedimentation or erosion									x	x
Release contaminants in soils, sediments	x	x	x	x		x	x			
Create excessive waste materials							x			
Affect areas of natural and scientific interest or provincially significant wetlands	x								x	x
Affect other (specify)										
Affect remoteness (access to inaccessible areas)										
Affect or obstruct navigation	x		x	x						
Affect other projects within a park or reserve										
Affect other projects outside a park or reserve	x	x	x	x	x					
Affect traffic patterns	x		x							

TABLE A.1
RELATIONSHIP BETWEEN DETAILED EVALUATION CRITERIA AND ENVIRONMENTAL ASSESSMENT SCREENING CRITERIA

Environmental Assessment Screening Criteria	Detailed Evaluation Criteria									
	Social Considerations						Natural Environment			
	Public Acceptance	Risk to Public	Constraint for Recreational Use	Negative Impact to Private Properties	Visual Character of the Area	Risk to Workers	Geochemistry	Terrestrial Habitats	Floodplain	Fish Habitats
Affect public or private recreation	x		x				x	x		
Commit a significant amount of a non-renewable resource (e.g. aggregates)								x		
Affect noise levels	x	x		x		x				
Affect views or aesthetics					x			x	x	
Be a precondition or justification for implementing another project										
Affect uses, persons or property outside park or reserve	x	x	x	x	x	x	x			
Affect other (specify)										
Affect cultural heritage or landscape features		x		x	x					
Displace people, businesses, institutions, or public facilities				x						
Affect community character, enjoyment of property, or local amenities	x		x	x				x	x	
Increase demands on government services or infrastructure										
Affect public health and/or safety		x				x			x	
Affect local economies				x						
Affect local businesses				x						
Affect other (specify)										
Affect First Nation reserves or communities										
Affect spiritual, ceremonial or cultural sites										
Affect traditional land or resource uses, or affect economic activities										
Affect Aboriginal values										
Affect other (specify)										

APPENDIX B

DETAILED COST OPINION

APPENDIX B

Opinions of Probable Construction Cost

In providing opinions of probable cost, MOE understands that CH2M HILL has no control over the cost or availability of labour, equipment or materials, or over market conditions or the potential Contractor's method of pricing. CH2M HILL makes no warranty, express or implied, that the bids or the negotiated cost of the Work will not vary from the opinion of probable construction cost.

CH2M HILL has made efforts to acquire area specific rates for materials, labour, and equipment whenever possible. The suitability of said materials to the intended purposes were not verified and will need to be determined prior to any construction activities. Where a local source or supplier could not be identified, industry budgetary tools such as the R.S. Means Company Inc. costing guide were used to assign a typical value. Appropriate regional coefficients were applied where necessary to adjust the typical costs to address regional conditions.

Each specific area of interest has been examined as an independent project. Any possible synergies associated with co-execution of various areas were ignored. Prices provided include the federal Goods and Services Tax (GST).

Volumes and areas were determined using existing available information. No additional investigations were performed to confirm or refute the estimates. Some estimates such as potential water volumes were based on engineering experience from other similar projects. Probable construction costs were based on typical weather conditions and may require adjustments due to extreme conditions.

Certain construction costs such as overhead, insurance, and various construction bonds will vary based on the potential Contractor. Financial strength, experience, and previous history all play a role in determining the rates that will be applied to a particular Contractor. These sums were determined as a percentage of the total costs based on industry averages.

Several of the options involve additional pumping to the arsenic treatment plant located in the Industrial Area. The application of a varied number of options over the four main areas will result in increases and decreases of the total treated water volume. At this conceptual stage it is difficult to determine whether there will be a net increase or decrease to the volume of water to be treated. Therefore, the operation and maintenance of the arsenic treatment plant has only been considered in the Industrial Area evaluation. Actual operation and maintenance costs over the last decade were used to develop a weighted-average and one standard deviation was added to this value in an effort to create a conservative estimate. Wastewater treatment considerations for all other areas were limited to collection and transmission to the equalization pond (i.e. equalization/storage basin).

Finally, a 15 percent contingency was added to the final capital cost (before taxes, overhead, insurance, and bonds) and a 5 percent contingency was added to the final operation and maintenance cost (before taxes).

The net present value costs presented in the following cost breakdown are the sum of the capital cost and the net present value of the operation and maintenance costs. The annual operation and maintenance costs have been transformed to a net present value assuming an effective interest rate of 5 percent and a planning horizon of 20 years. The effective interest rate includes inflationary effects. It should be noted that operation and maintenance effort and costs will be required beyond the 20 year horizon. The 20-year period was selected based on the assumption that it is a reasonable period for budgetary planning purposes.

Breakdown of Major Cost Items for the Comprehensive Remediation Alternatives

	Alternative 1 *Consolidate and Cover Wastes*	*Alternative 2* *Consolidate and Cover Wastes GW/SW Flow Diversion*	*Alternative 3* *Consolidate and Cover Wastes GW/SW Flow Diversion Selected Stabilization/Solidification*	*Alternative 4* *Consolidate and Cover Wastes GW/SW Flow Diversion Selected Offsite Disposal*	*Alternative 5* *Consolidate and Cover Wastes GW/SW Flow Diversion Enhanced Groundwater Collection*
A. Capital Costs					
Site Preparation	$204,000	$204,000	$204,000	$204,000	$204,000
Demolition	$729,500	$729,500	$729,500	$729,500	$729,500
Riverbank Reconstruction	$852,000	$852,000	$852,000	$852,000	$852,000
Full Encapsulation	NA	NA	NA	NA	NA
Engineered Cover and Simple Earth Cap (with Consolidation)	$7,625,000	$7,625,000	$7,625,000	$7,625,000	$7,625,000
Engineered Cover and Simple Earth Cap (No Consolidation)	NA	NA	NA	NA	NA
Selected Stabilization/Solidification (In-Situ, 14,000 m^3)	NA	NA	NA	NA	NA
Selected Stabilization/Solidification (Ex-Situ, 14,000 m^3)	NA	NA	$3,900,000	NA	NA
Selected Offsite Disposal (14,000 m^3)	NA	NA	NA	$8,900,000	NA
Groundwater and Surface Water Flow Diversion (enhancement)	NA	$211,000	$211,000	$211,000	$211,000
Enhanced Groundwater Collection (enhancement)	NA	NA	NA	NA	$88,000
Subtotal	$9,410,500	$9,621,500	$13,521,500	$18,521,500	$9,709,500
Overhead, Insurance, and Bonds	$735,[illegible]	$91[illegible]	$1,150,[illegible]	$1,[illegible]	$8[illegible]
Total (incl. Enhancements)	**$10,205,500**	**$10,434,500**	**$14,671,500**	**$20,121,500**	**$10,529,500**
Total (excl. Enhancements)	**NA**	**$10,223,500**	**$14,460,500**	**$19,910,500**	**$10,230,500**
B. Annual Operation and Maintenance Costs					
Treatment Plant Operations					
Annual Operating Costs	$550,000	$550,000	$550,000	$550,000	$550,000
Sludge Disposal (assuming 550 tonnes/yr)	$170,000	$170,000	$170,000	$170,000	$170,000
Enhanced Groundwater Collection	NA	NA	NA	NA	$11,000
Maintenance					
Engineered Cover and Simple Earth Cap	$18,000	$18,000	$18,000	$18,000	$18,000
General	$60,000	$60,000	$60,000	$60,000	$60,000
Contingency	$40,000	$40,000	$40,000	$40,000	$40,000
Total	$838,000	$838,000	$838,000	$838,000	$849,000
Net Present Value of Annual O&M Costs (20-year period) (incl. Enhancements)	**$10,970,000**	**$10,970,000**	**$10,970,000**	**$10,970,000**	**$11,110,000**
Net Present Value of Annual O&M Costs (20-year period) (excl. Enhancements)	**NA**	**NA**	**NA**	**NA**	**$10,970,000**
C. Net Present Value Capital and O&M Costs					
NPV of Capital and O&M Costs (incl. Enhancements)	**$21,175,500**	**$21,404,500**	**$25,641,500**	**$31,091,500**	**$21,639,500**
NPV of Capital and O&M Costs (excl. Enhancements)	**NA**	**$21,193,500**	**$25,430,500**	**$30,880,500**	**$21,200,500**

All capital costs include GST and a 15% contingency (before taxes, overhead, insurance, and bonds)
All operation and maintenance costs include GST and a 5% contingency (before taxes)

Breakdown of Major Cost Items for the
Comprehensive Remediation Alternatives

	Alternative 6 *Consolidate and Cover Wastes* *GW/SW Flow Diversion* *Selected Stabilization/Solidification* *Enhanced Groundwater* *Collection*	*Alternative 7* *Consolidate and Cover Wastes* *GW/SW Flow Diversion* *Selected Offsite Disposal* *Enhanced Groundwater* *Collection*	*Alternative 8* *Cap and Cover Wastes in Place*	*Alternative 9* *Cap and Cover Wastes in Place* *GW/SW Flow Diversion*	*Alternative 10* *Cap and Cover Wastes in Place* *GW/SW Flow Diversion* *Selected Stabilization/Solidification*
A. Capital Costs					
Site Preparation	$204,000	$204,000	$204,000	$204,000	$204,000
Demolition	$729,500	$729,500	$729,500	$729,500	$729,500
Riverbank Reconstruction	$852,000	$852,000	$852,000	$852,000	$852,000
Full Encapsulation	NA	NA	NA	NA	NA
Engineered Cover and Simple Earth Cap (with Consolidation)	$7,625,000	$7,625,000	NA	NA	NA
Engineered Cover and Simple Earth Cap (No Consolidation)	NA	NA	$12,190,000	$12,190,000	$12,190,000
Selected Stabilization/Solidification (In-Situ, 14,000 m^3)	NA	NA	NA	NA	NA
Selected Stabilization/Solidification (Ex-Situ, 14,000 m^3)	$3,900,000	NA	NA	NA	$3,900,000
Selected Offsite Disposal (14,000 m^3)	NA	$8,900,000	NA	NA	NA
Groundwater and Surface Water Flow Diversion (enhancement)	$211,000	$211,000	NA	$400,000	$400,000
Enhanced Groundwater Collection (enhancement)	$88,000	$88,000	NA	NA	NA
Subtotal	$13,609,500	$18,609,500	$13,975,500	$14,375,500	$18,275,500
Overhead, Insurance, and Bonds	[illegible]	$1,600,000	[illegible]	[illegible]	[illegible]
Total (incl. Enhancements)	**$14,760,500**	**$20,209,500**	**$15,155,500**	**$15,589,500**	**$19,825,500**
Total (excl. Enhancements)	**$14,461,500**	**$19,910,500**	**NA**	**$15,189,500**	**$19,425,500**
B. Annual Operation and Maintenance Costs					
Treatment Plant Operations					
Annual Operating Costs	$550,000	$550,000	$550,000	$550,000	$550,000
Sludge Disposal (assuming 550 tonnes/yr)	$170,000	$170,000	$170,000	$170,000	$170,000
Enhanced Groundwater Collection	$11,000	$11,000	NA	NA	NA
Maintenance					
Engineered Cover and Simple Earth Cap	$18,000	$18,000	$54,000	$54,000	$54,000
General	$60,000	$60,000	$60,000	$60,000	$60,000
Contingency	$40,000	$40,000	$40,000	$40,000	$40,000
Total	$849,000	$849,000	$874,000	$874,000	$874,000
Net Present Value of Annual O&M Costs (20-year period) (incl. Enhancements)	**$11,110,000**	**$11,110,000**	**$11,440,000**	**$11,440,000**	**$11,440,000**
Net Present Value of Annual O&M Costs (20-year period) (excl. Enhancements)	**$10,970,000**	**$10,970,000**	**NA**	**NA**	**NA**
C. Net Present Value Capital and O&M Costs					
NPV of Capital and O&M Costs (incl. Enhancements)	**$25,870,500**	**$31,319,500**	**$26,595,500**	**$27,029,500**	**$31,265,500**
NPV of Capital and O&M Costs (excl. Enhancements)	**$25,431,500**	**$30,880,500**	**NA**	**$26,629,500**	**$30,865,500**

All capital costs include OST and a 15% contingency (before taxes, overhead, insurance, and bonds)
All operation and maintenance costs include OST and a 5% contingency (before taxes)

Breakdown of Major Cost Items for the Comprehensive Remediation Alternatives

	Alternative 11 *Cap and Cover Wastes in Place GWISW Flow Diversion Selected Offsite Disposal*	*Alternative 12* *Cap and Cover Wastes in Place GWISW Flow Diversion Enhanced Groundwater Collection*	*Alternative 13* *Cap and Cover Wastes in Place GWISW Flow Diversion Selected Stabilization/Solidification Enhanced Groundwater Collection*	*Alternative 14* *Cap and Cover Wastes in Place GWISW Flow Diversion Selected Offsite Disposal Enhanced Groundwater Collection*	*Alternative 15* *Full Encapsulation*	*Alternative 16* *Full Encapsulation Enhanced Groundwater Collection*
A. Capital Costs						
Site Preparation	$204,000	$204,000	$204,000	$204,000	$204,000	$204,000
Demolition	$729,500	$729,500	$729,500	$729,500	$729,500	$729,500
Riverbank Reconstruction	$852,000	$852,000	$852,000	$852,000	$852,000	$852,000
Full Encapsulation	NA	NA	NA	NA	$9,252,000	$9,252,000
Engineered Cover and Simple Earth Cap (with Consolidation)	NA	NA	NA	NA	NA	NA
Engineered Cover and Simple Earth Cap (No Consolidation)	$12,190,000	$12,190,000	$12,190,000	$12,190,000	NA	NA
Selected Stabilization/Solidification (In-Situ, 14,000 m^3)	NA	NA	NA	NA	NA	NA
Selected Stabilization/Solidification (Ex-Situ, 14,000 m^3)	NA	NA	$3,900,000	NA	NA	NA
Selected Offsite Disposal (14,000 m^3)	$8,900,000	NA	NA	$8,900,000		
Groundwater and Surface Water Flow Diversion (enhancement)	$400,000	$400,000	$400,000	$400,000	NA	NA
Enhanced Groundwater Collection (enhancement)	NA	$88,000	$88,000	$88,000	NA	$88,000
Subtotal	$23,275,500	$14,483,500	$18,363,500	$23,383,500	$11,037,500	$11,125,500
Overhead, Insurance, and Bonds	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total (incl. Enhancements)	**$25,245,500**	**$15,684,500**	**$19,915,500**	**$25,343,500**	**$11,969,500**	**$12,075,500**
Total (excl. Enhancements)	**$24,846,500**	**$15,196,500**	**$19,427,500**	**$24,855,500**	**NA**	**$11,987,500**
B. Annual Operation and Maintenance Costs						
Treatment Plant Operations						
Annual Operating Costs	$550,000	$550,000	$550,000	$550,000	$550,000	$550,000
Sludge Disposal (assuming 550 tonnes/yr)	$170,000	$170,000	$170,000	$170,000	$170,000	$170,000
Enhanced Groundwater Collection	NA	$11,000	$11,000	$11,000	NA	$11,000
Maintenance						
Engineered Cover and Simple Earth Cap	$54,000	$54,000	$54,000	$54,000	$18,000	$18,000
General	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000
Contingency	$40,000	$40,000	$40,000	$40,000	$40,000	$40,000
Total	$874,000	$885,000	$885,000	$885,000	$838,000	$849,000
Net Present Value of Annual O&M Costs (20 year period) (incl. Enhancements)	**$11,440,000**	**$11,580,000**	**$11,580,000**	**$11,580,000**	**$10,965,000**	**$11,110,000**
Net Present Value of Annual O&M Costs (20 year period) (excl. Enhancements)	**NA**	**$11,440,000**	**$11,440,000**	**$11,440,000**	**NA**	**$10,970,000**
C. Net Present Value Capital and O&M Costs						
NPV of Capital and O&M Costs (incl. Enhancements)	**$36,685,500**	**$27,264,500**	**$31,495,500**	**$36,923,500**	**$22,934,500**	**$23,185,500**
NPV of Capital and O&M Costs (excl. Enhancements)	**$36,285,500**	**$26,636,500**	**$30,867,500**	**$36,295,500**	**NA**	**$22,957,500**

All capital costs include GST and a 15% contingency (before taxes, overhead, insurance, and bonds)
All operation and maintenance costs include GST and a 5% contingency (before taxes)